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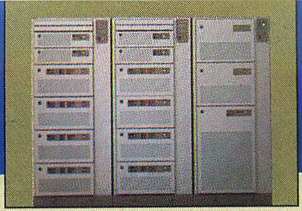

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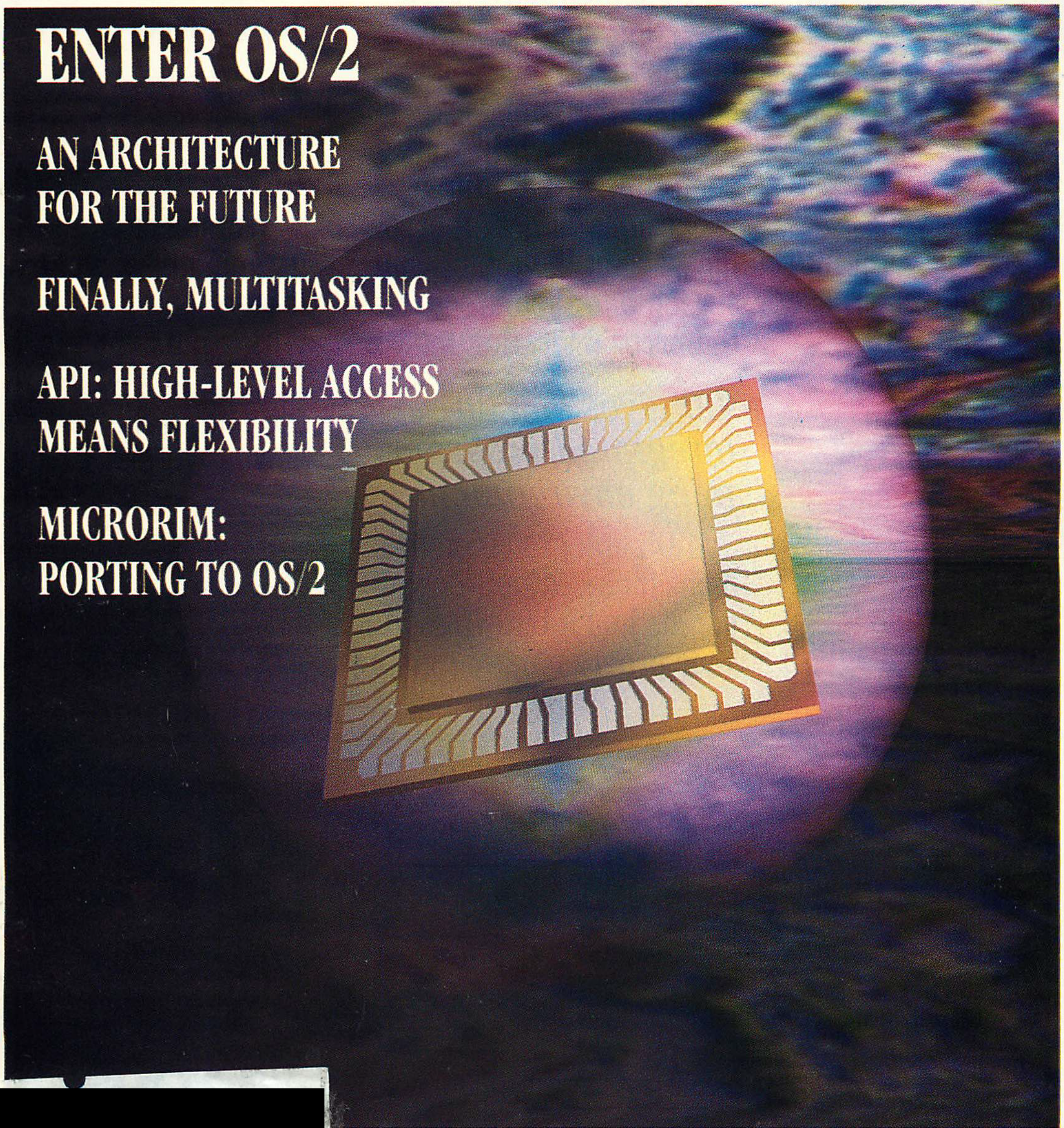

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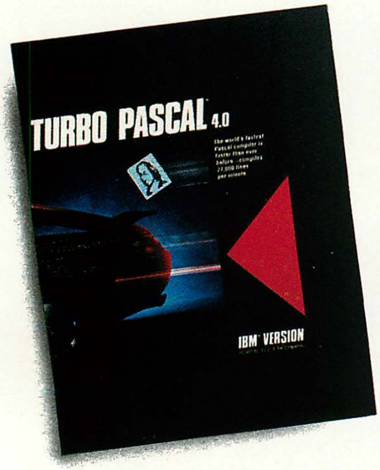

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4.0's cursor automatically lands on any trouble spot

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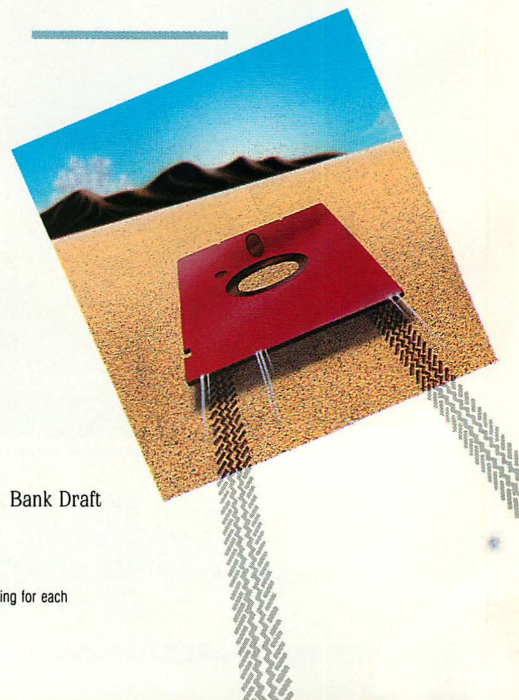

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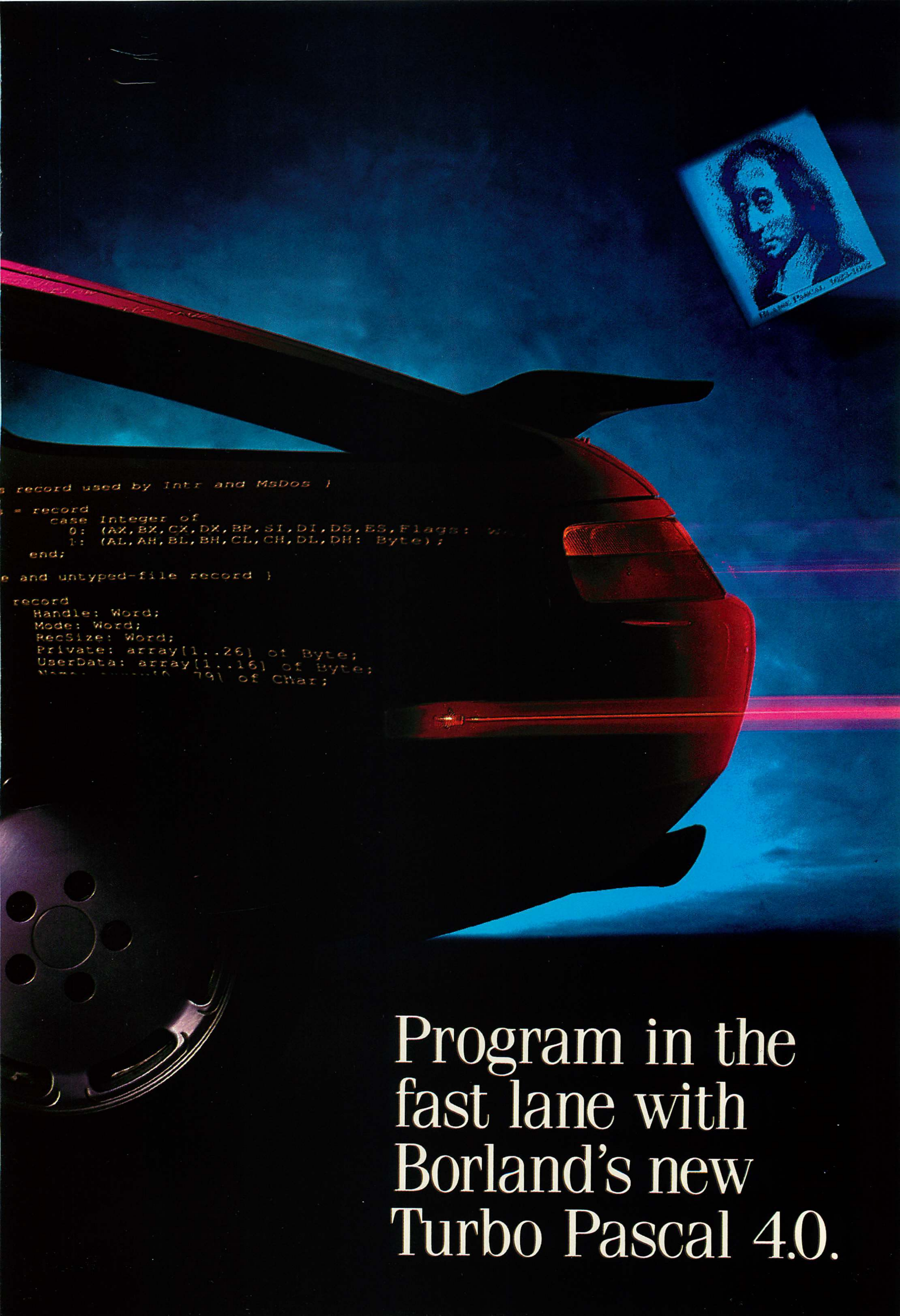
record used by Intr and MsDos }
= record
case Integer of
0: (AX,BX,CX,DX,BP,SI,DI,DS,ES,Flags:
1: (AL,AH,BL,BH,CL,CH,DL,DH: Byte);
end;
and untyped-file record }
record
Handle: Word;
Mode: Word;
RecSize: Word;
Private: array[1..26] of Byte;
UserData: array[1..16] of Byte;
79] of Char;
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- Interactive error detection/location
- Includes a command line version of the compiler

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Sieve (25 iterations)

	Turbo Pascal 4.0	Turbo Pascal 3.0
Size of Executable File	2224 bytes	11682 bytes
Execution speed	9.3 seconds	9.7 seconds

Sieve of Eratosthenes, run on an 8MHz IBM AT

Since the source file above is too small to indicate a difference in compilation speed we compiled our GOMOKU program from Turbo Gameworks to give you a true sense of how much faster 4.0 really is!

Compilation of GO.PAS (1006 lines)

	Turbo Pascal 4.0	Turbo Pascal 3.0
Compilation speed	2.2 seconds	3.6 seconds
Lines per minute	27,436	16,750

GO.PAS compiled on an 8 MHz IBM AT

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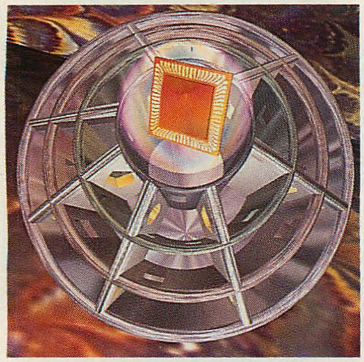

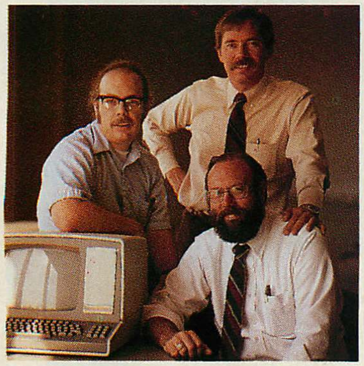

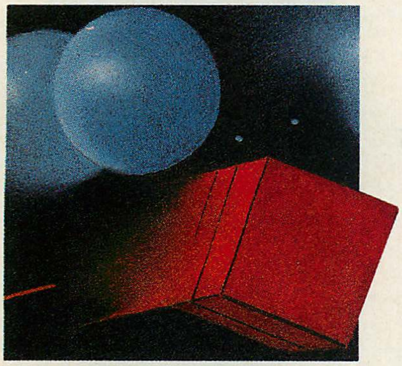

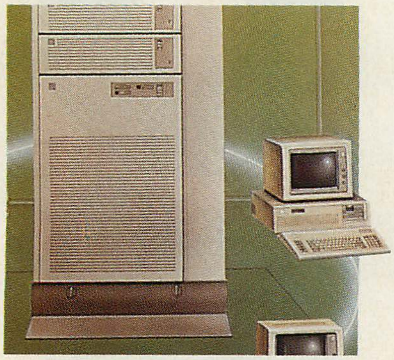

COVER SUITE: ENTER OS/2

The wait may be killing us all—but just another few months and OS/2 will come on the scene to clear the air itself. Until then, our cover suite unravels the mystery of OS/2.
Cover: Computer graphic by Joe Pasquale / Editel

TO LIVE AND BREATHE OS/2

On the tails of the OS/2 announcement, technical editor Ted Mirecki was winging his way to Microsoft to find out more about this significant new operating system. For weeks he ate, slept, and breathed OS/2 while preparing this month's cover suite. "We tried to get across some of the excitement I and the authors felt while exploring this new territory," Mirecki said. "We hope to pique people's interest in writing OS/2 applications." After his total immersion in OS/2, Mirecki came up feeling positive about the future of the operating system and ready to continue our coverage of the OS/2 story as it develops.

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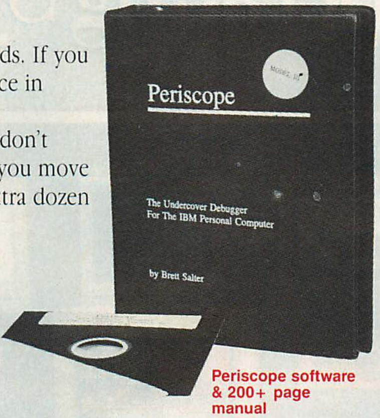

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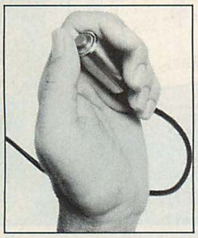
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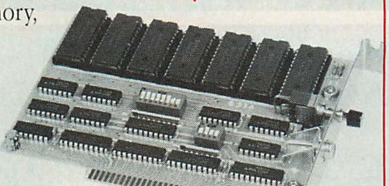
Periscope I Board

Periscope III has a board with 64K of write-protected RAM, which performs the same function as the Periscope I protected memory. AND...

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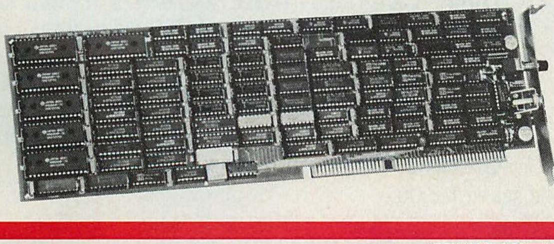
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Periscope II-X user

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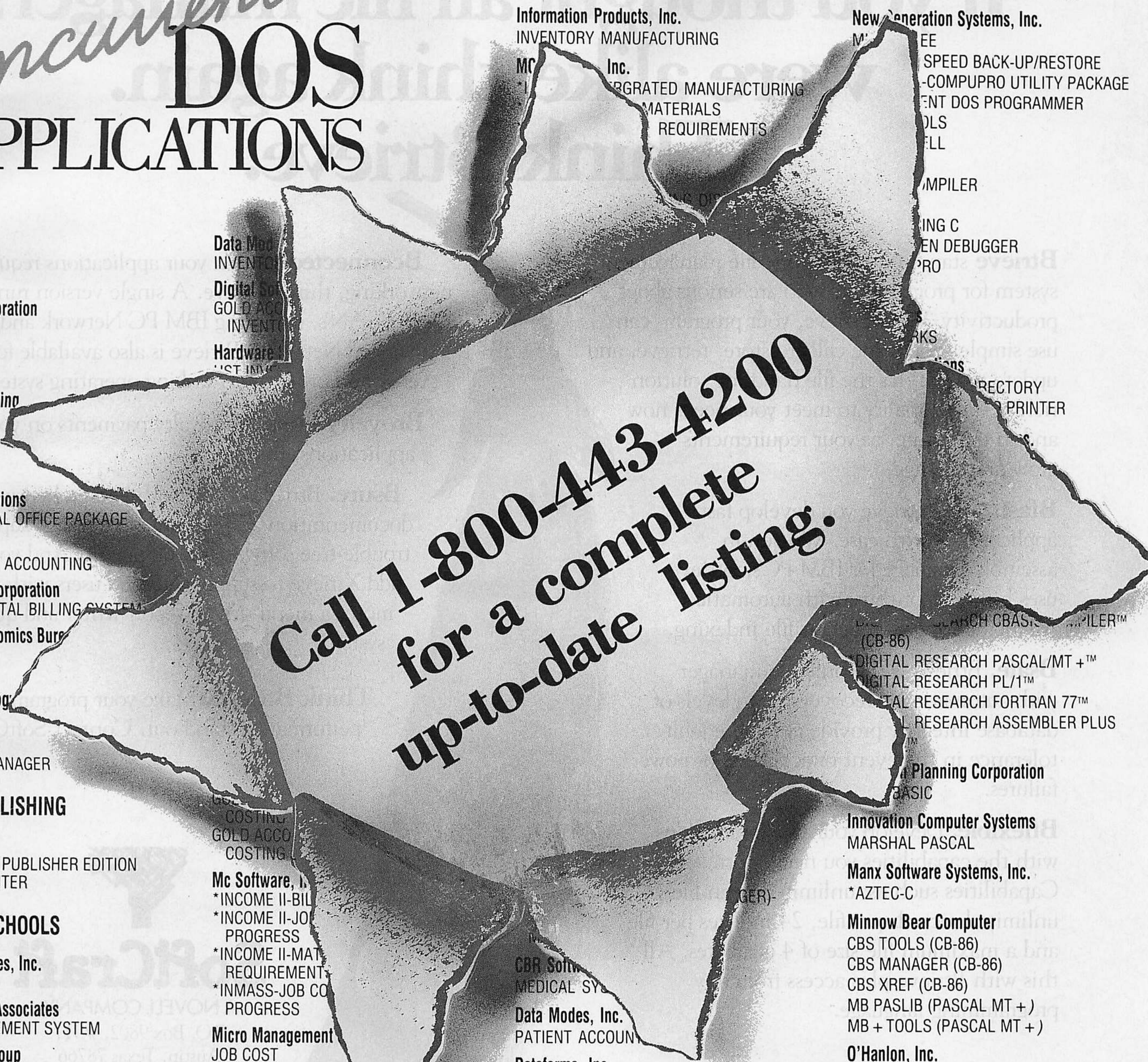

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JULIE ANDERSON

SYSTEMS PERSPECTIVE

JAnderson

Evolving Systems

OS/2 raises separate questions for developers and integrators, but for both it is a significant advance over DOS 3.3.

With OS/2 on the brink of release and 80286 and 80386 processors proliferating, these are exciting times. PCs in corporations are evolving from terminal emulators and personal productivity workstations into platforms for developing and installing strategic applications.

We are evolving, too, as you can see from our updated logo and cover graphics, table of contents page (now two pages), cover story (now a group of articles—more on that later), and the addition of this very column.

In this issue we address a topic critical to the future of personal computing: the advent of OS/2. We have been waiting since August 1984, when the IBM PC/AT was announced, for an operating system that would allow applications to exploit the 16MB address space of the 80286 and that would support true multitasking. Stopgap measures such as expanded memory and context-switching environments have helped, but they have levied high tariffs on both developers and users.

To take advantage of expanded memory, developers have had to manage the bank-switched memory; to use context-switching environments, users must turn into job schedulers to multitask our ill-behaved programs on top of a nonreentrant DOS. I believe that OS/2, with all its complexity, will be a simpler environment for both developers and end users.

Because OS/2 is not scheduled for release until 1988, exactly what OS/2 offers developers and users has been known only by attendees of Microsoft's OS/2 seminars or those who have arranged for a beta-test version. It is for this particular reason—to define and assess its advantages and disadvantages—that technical editor Ted Mirecki compiled our coverage.

In "Enter OS/2," (p. 52) Mirecki describes the OS/2 user interface, including the Session Manager. "An Architecture for the Future" (p. 66) is the pivotal article of the suite; in "Multiple Tasks," (p. 90) we take a closer look at multitasking and interprocess communications. "The Flexible Interface" (p. 110) describes the OS/2 applications program interface.

What you will not find in our coverage are details about the Presentation Manager. Although its specifications have been published, no release date has been announced, and we have not seen any executable code. When we have concrete information, we will provide a similar suite of cover articles on the Presentation Manager.

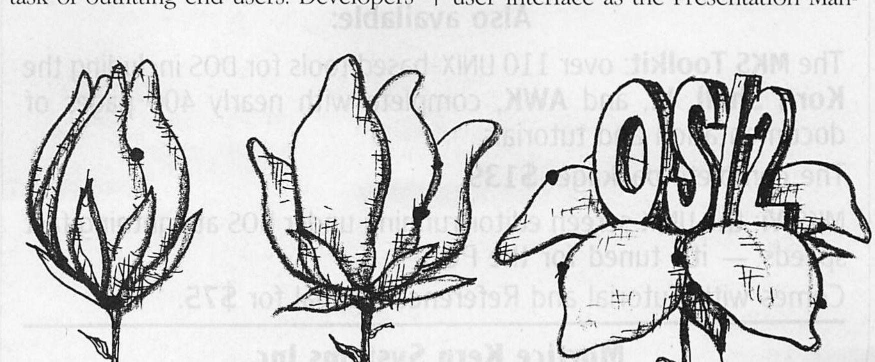
We prepared our OS/2 coverage using a prerelease version of the product; thus we are not reporting bugs (for now). Neither, apparently, are the developers working with OS/2. Mark Mackaman, Microsoft's OS/2 product manager, claims that fewer than a dozen bugs have been reported to the company, none serious enough to warrant redistribution of the kernel. Microsoft has not released a new version of the kernel since May 1987.

What OS/2 means to you depends on whether you are a developer or a systems integrator—a consultant or a corporate PC manager faced with the task of outfitting end users. Developers can scarcely afford to ignore the opportunities of OS/2. Editorial director Will Fastie explores these opportunities in his New Directions column, which debuts in this issue on page 21.

The biggest decision developers may have to make is not whether to convert to OS/2, but which migration path to follow. Should they move directly to the new operating system without benefit of the graphical user interface, or should they take a detour to Microsoft Windows while waiting for the Presentation Manager.

For character-based applications written in C that groan within the confines of 640KB, moving directly to OS/2 is relatively simple. This is similar to the situation faced by the managers at Microrim when they began converting R:BASE System V to OS/2. The OS/2 version was up and running in time for IBM's big PS/2 and OS/2 announcement last April. Microrim's story is told in "Porting to OS/2" (p. 140). Numerous other vendors have assured us that they are poised with OS/2 products that will follow closely on the heels of IBM's release of the operating system.

Microsoft recommends that current DOS applications first be ported to Windows 2.0, which bears the same user interface as the Presentation Man-



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ager and will run in the real-mode DOS environment of OS/2. The Windows application can be converted later to the Presentation Manager and OS/2. Unless a graphical user interface is essential to an application, this migration path may leave you, the developer, out in the cold. While your application runs only under Windows, your competitors' products likely will be running under OS/2. Further, we do know that the conversion from Windows 2.0 to the Presentation Manager is nontrivial, because it involves a new graphical program interface (GPI). Microsoft is developing tools that should aid in the conversion, but final work must be done by hand.

Systems integrators will likely deliver OS/2 to end users when compelling applications arrive—those that exploit the capabilities of OS/2. Only then will the cost of additional memory (minimum of 1.5MB to 2MB) and the $205 delta between the price of DOS and OS/2 be justified.

OS/2 is not without problems, aggravated by the deficiencies of the 80286 processor. Although OS/2 will run on 80386-based systems, it is written to the specifications of the 80286—supporting 16-bit registers and a maximum physical memory size of 16MB in 64KB segments, with virtual addressing to 1GB. Because the 80286 lacks the I/O permission bit-map present in the 80386, the operating system has limited control over an application running in real mode. Therefore, in OS/2 an application in the real-mode DOS Environment is given CPU time only when it is in the foreground, and it is possible for an application running in the DOS Environment to crash the entire system. Nevertheless, OS/2 represents a significant advance over DOS 3.3 as a development platform and an end-user environment. We expect to be covering OS/2 for many months to come.

This brings me to the other topics we will cover in the coming months. In addition to our cover suites, we will include articles selected from applications development, operating environments, data management, local area networks, systems integration, expert systems, mainframe and minicomputer connections, and PC-to-PC communications. Beginning this month and into the next year, you will see new elements being added to *PC Tech Journal*. All these changes will improve the coverage of topics essential to performing your job as a systems developer and integrator.

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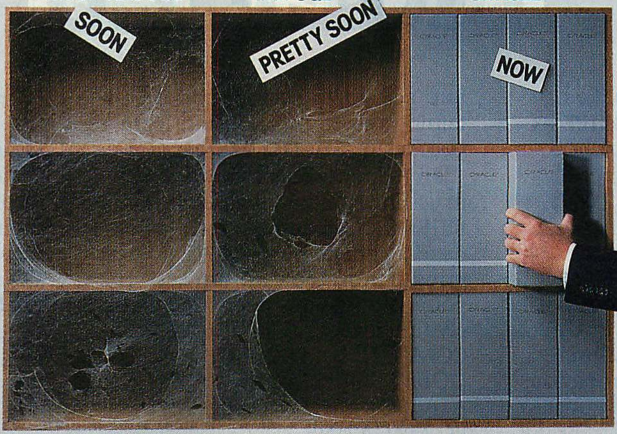

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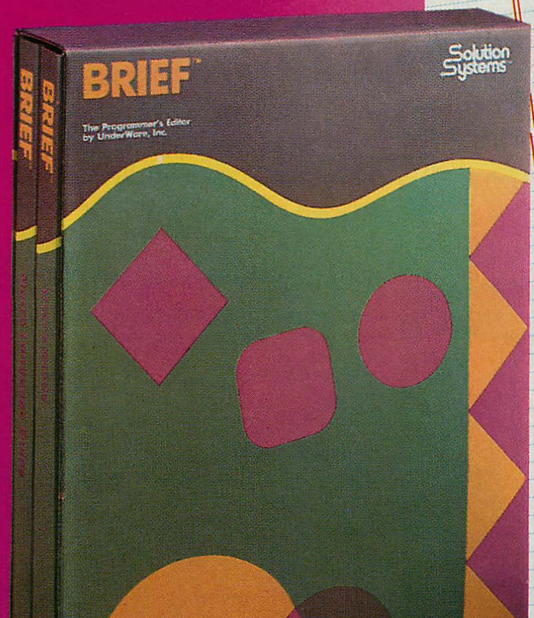

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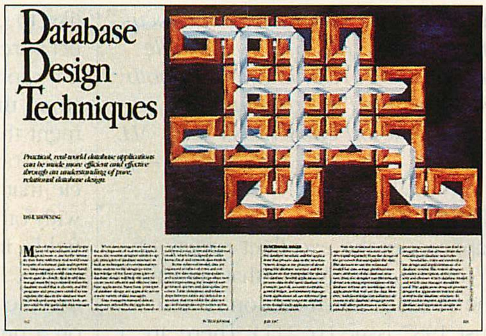
LETTERS



IT'S ALL RELATIONAL

The article "Database Design Techniques" (Dave Browning, July 1987, p. 112) was informative , but I believe it does not provide sufficient explanation of some key concepts of "pure, relational design" necessary for software developers to make database applications "more efficient and effective." These concepts must be explored in more detail because their implementation is absent in most database products on the market.

The first concept is the relationship between data and its definition, or "attribute." One difference between the relational database and other models, such as hierarchical and network databases, is that data, the associated applications, and the data definition are physically separate. An example of the pain that occurs when data and its definition are combined is the need to change the human resources database application when the employee number field increases in length from eight to nine. In the true relational model, the employee number field length could change without affecting the database application; of course, this is not always the way things work with today's database products.

The second concept is the importance of normalization to the relational operators. The author refers to join, intersect, and union as data manipulation commands that act on relational data. In the relational model, these "commands" are relational operators that correspond to mathematical set theory operators, and the rules of normalization correspond to theorems that support set theory operations. Data that are not normalized can be relationally operated on in today's software because the implementation of relational operators is not mathematically accurate; however, database designs like these would be unworkable in a truly relational system.

The last concept is that index files do *not* exist in the true relational model. Today's databases use separate index files as an alternative to the sophisticated software and hardware required to emulate the mathematics of relational operators.

The gap between the true relational database and the current generation of software and hardware must be eliminated before we will be able to take advantage of the functionality of relational models. Our challenge is to sufficiently understand the relational model in order to implement it in very powerful hardware and software. This is indeed a significant challenge for applications developers.

Don Awalt
Cockeysville, MD

Mr. Awalt offers for discussion several points concerning relational database theory and current relational data manager product implementations. These points are interesting, but beyond the scope of the article. The article was meant to address the topic of database design techniques in the context of current real-world technology, rather than to fully explore the theoretical considerations that were raised in Mr. Awalt's letter. A proper treatment of these points would require a substantially more theoretical article.

—Dave Browning

SHORT ON DOS 3.3

I read the August 1987 issue of PC Tech Journal with considerable interest. Here are my views on some of the articles. First, your series of articles on the PS/2 is superb; they probably are the most comprehensive that I have seen to date on the subject.

I felt that the coverage given to DOS 3.3 ("Twilight of DOS," Julie Anderson, p. 180) was insufficient for the readership that *PC Tech Journal* addresses. I was pleased to find the explanation of the DOS file handle table on page 191. This information enabled me to adjust some software that I have written so that it can handle the DOS 3.3 handle table.

However, in the third column on page 190, Ms. Anderson makes an error of omission in describing which DOS function calls assign a handle to a file. In addition to the ones she cites, functions 5A (create temporary file) and 5B (create new file) also result in DOS assigning a handle. These calls are new with DOS 3.0, and unless you write software that uses or must be aware of these function calls, they easily can escape your attention. I found the detail about the new DOS 3.3 function calls to be sorely lacking. I had the expectation that the article would explain the register meanings upon calling and returning from these functions.

With the advent of the PS/2, IBM finally has awakened to the performance advantage of disk cache software. So, too, has *PC Tech Journal*, it seems. This surprises me, because other publications in the PC industry have (and rightfully so) touted disk cache software for some time. Not coincidentally, I'm afraid, I also have come across many software developers who were totally unaware of the availability of disk cache packages for PCs. In fact, at a Microsoft Windows Development Seminar I attended in Boston earlier this year, the assertion that Microsoft developers used machines equipped with disk cache and AboveBoards set off a clamor that didn't stop for about 10 minutes. Amazingly, most of the developers in the room had not heard of such software for PCs! On the one hand, *PC Tech Journal* is to be chided for keeping its readership in the dark for such a long time, but complimented for finally getting the word out about disk cache.

Ben Myers
Harvard, MA

Mr. Myers is correct to point out my oversight: in addition to the DOS function calls that were mentioned in the article, function calls 5AH (create unique file) and 5BH (create new file) also assign a file handle. As for his comment about not listing the register contents upon calling and returning from a function call, the article was not intended to be a substitute for the product's technical reference manual. However, in this particular case, listing the register contents would have been a good idea, since IBM incorrectly documents function calls 67H (set handle count) and 68H (commit file). In both cases, AX is listed as containing the function code on entry rather than AH.

—JA

LICENSE TO . . .

We appreciate the excellent review of Fast Trax by Peter Aitken that appeared in the Product Watch section of your August 1987 issue (p. 211). There are a couple of points, however, that I would like to clarify with regard to the product's treatment in this review.

Apparently, Mr. Aitken misunderstood the nature of the licensing agreement that Mark Elfield included with Fast Trax. Mr. Aitken stated in the article that Fast Trax legally can be shared with others; this is contrary to Mr. Elfield's intention (explicitly stated) that a single, licensed user may personally use the product to optimize hard disks on a number of machines. To avoid this confusion in the future, the license agreement has been clarified in the new FastTrax documentation.

In addition, we would like to inform your readers that Fast Trax is now published by Bridgeway Publishing, 2165 E. Francisco Blvd., Suite A1, San Rafael, CA 94912, 415/485-0948.

David W. Chard
Bridgeway Publishing
San Rafael, CA

PROBLEM LISTING

I am a long-term subscriber to your excellent magazine and this is the first time that I have written to you to complain about anything. On page 49 of the September 1987 issue, you offered an "Underline Fix for the EGA" (Tech Notebook 80, Gerry Kaplan). I entered the code exactly as it was printed, but when I tried to assemble it, my MASM program displayed an error in line 5, which happens to be:

```
ASSUME CS:CODESEG, DS:COSESEG
```

I assumed that COSESEG was a typographical error and changed it to read CODESEG, and the code assembled fine. I converted to a .COM file, ran it, and it hung up my IBM PC!

Was there a typo in COSESEG? Will UNDRLINE.ASM run on an IBM PC with an NEC Multisync EGA Monitor connect to an NEC GB-1 Multisync Color Graphics Adapter? I would appreciate your advice.

Do you have facilities for readers to download the programs that are published in *PC Tech Journal*? If so, what is the telephone number and how can it be accessed? I attempted to reach your offices on the PCTECHline number that is listed on the masthead on page 4, but I could not make contact, either by voice or computer.

Frank Diamond
Whiting, NJ

We appreciate Mr. Diamond pointing out this error. When UNDERLIN.ASM was turned in for publishing, an obsolete version of the file was inadvertently

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substituted. The correct version of the ASSUME directive as follows:

ASSUME CS:CODESEG

DS should not be mentioned at all. This causes the assembler to generate CS override prefixes for the far jump and call instructions near the start of the resident portion; without them, the program crashes the system.

Programs and other files (both text and binary) are available for downloading from PCTECHline at 301/740-8383. The modem parameters are 1200 bits per second (bps), no parity, 8 data bits, 1 stop bit; note that 2400-bps transmission is temporarily disabled.

Unfortunately, yet another error crept in as the UNDERLIN program was loaded onto PCTECHline—the source file originally loaded was yet another incorrect version. Although it would assemble and run, it did not implement all of the features of the published version. The correct program has been available for downloading since September 22. My apologies to readers for any inconvenience that these errors may have caused.

—TM

DOESN'T C

Perhaps I am extremely naive, but I fail to see any benefits to programmers coding application programs in C.

The C language seems to me to be a super macro assembler and almost as low-level in its constructs as an assembler. I have been programming applications (such as payroll, general ledger, and so on) on IBM mainframes, minicomputers, and microcomputers for 20 years and have *never* needed to code a single line of assembly language.

The reason why a programmer would choose a low-level language such as C or assembly to code application programs (as opposed to system or utility programs) totally escapes me.

Application programs normally require maintenance from time to time by someone other than the original programmer. For that reason, it behooves one to choose the highest level language possible to minimize the maintenance efforts.

On IBM microcomputers, I program in BASIC using the IBM BASIC Compiler. I can detect no difference in execution speed of a program written in assembly language, C, or compiled BASIC, and, if I did, I would suggest that the user buy a faster machine. Hardware is a lot cheaper than programmer's time, and, if a user balks at spending $4,000 to $6,000 for an IBM PC that has the capability of mainframes that used to cost hundreds of thousands of dollars, then I would suggest that the user cannot afford me either, and to quit wasting my time. Arrogant, perhaps, but those are the facts.

As of this writing, it appears that the only way to interface with the OS/2 Presentation Manager is with the C language. IBM has announced BASIC, COBOL, assembly, and C compilers for OS/2, but only Microsoft is delivering anything yet and it remains to be seen whether the Presentation Manager interface is possible with IBM's BASIC and COBOL compilers.

Please enlighten me if you can. I cannot find anything in C that I cannot do in BASIC quicker and with much less debugging effort. Where is the advantage, except possibly job security, of which I have plenty already.

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MICROSOFT LANGUAGES NEWSLETTER VOL. 2, NO. 11

Dear Reader:

When we introduced the Microsoft® Languages Newsletter in 1985, we had just one goal in mind: improving communications with the people who use Microsoft languages.

We wanted to communicate to you the technical advances underway at Microsoft and get feedback from you about how we could make additional improvements to our products.

Everything we do at Microsoft is built around a vision: to create the software that puts a computer on every desk and in every home. We know that many of you share that vision with us and are working toward it in the development of your own programs.

We know that in order to make this vision come true, we need to supply you with effective development tools—such as the Microsoft CodeView® debugger, Microsoft QuickBASIC and QuickC™ programming languages, and Microsoft C Optimizing Compiler.

But we also know that we need your help to achieve our vision of the future. That's why, back in January, we asked you to share your visions of the ideal programming environment. Your response was tremendous. In fact, we're already exploring many of your ideas, including language enhancements to support windowing environments, a general programmer's editor, and a "super" MAKE facility.

These are just a few examples of how your ideas and suggestions have helped us shape our future product plans. From the very beginning of the Languages Newsletter, your feedback has been invaluable. And that's why we want you to be part of some important changes.

As we look to the next couple of years, we recognize that developers will want to create more global solutions; solutions that will encompass languages, operating environments, and networking. With that in mind, we have decided to transfer our resources from the Languages Newsletter to the Microsoft Systems Journal*—a bimonthly publication covering the broad scope of systems-related issues.*

Because the Microsoft Systems Journal *will include much of the information you're used to getting from the Languages Newsletter, and because we value your active participation in shaping future products, we'd like to offer you a free issue of the* Microsoft Systems Journal.

The issue you'll receive contains detailed information about Microsoft Operating System/2 and the Microsoft OS/2 presentation manager. It gives you the inside story about where we're going, including an interview with Gordon Letwin, one of the chief architects of Microsoft OS/2. There's also a special section entitled "Ask Dr. Bob," with detailed Q&A's on subjects ranging from Microsoft Windows printer drivers to using Microsoft C math library functions in an assembly program.

To arrange to get your OS/2 issue and the Microsoft Systems Journal *on a regular basis, just call toll free 1-800-533-6625 (in Ohio, call 1-800-633-3157). We'll sign you up for the OS/2 issue plus six regular issues (a year's subscription) at the special introductory price of $34.95.* If after examining the OS/2 issue you decide you don't want to continue your subscription, just write "Cancel" across the invoice, return it to us, and you can keep the OS/2 issue free of charge.*

Thanks for your support of the Microsoft Languages Newsletter. We hope you'll find the Microsoft Systems Journal *even more valuable in your programming efforts.*

Sincerely,

Bill Gates

Bill Gates
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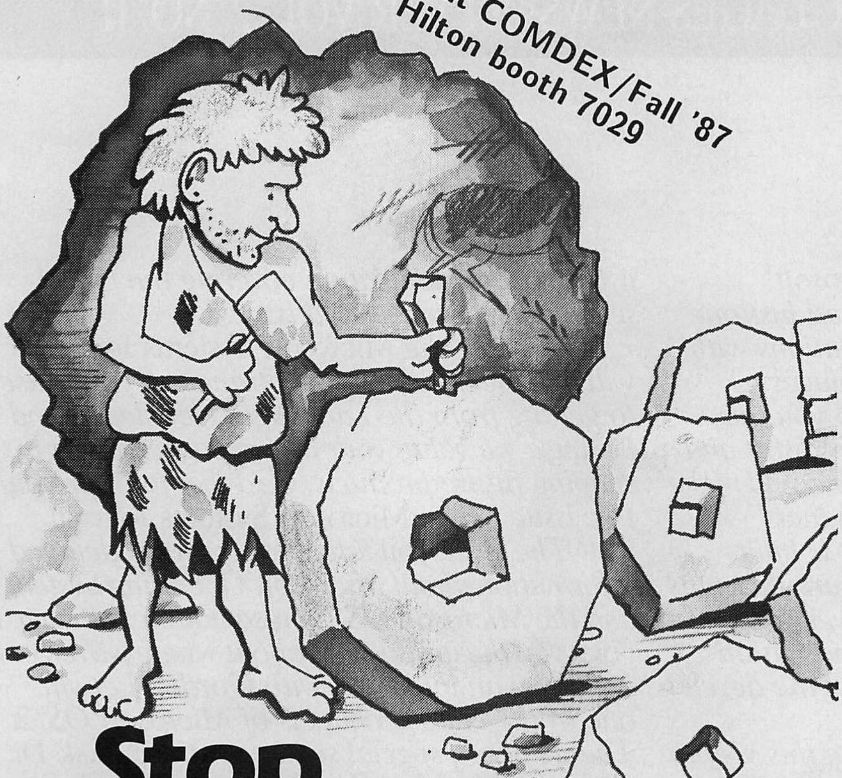

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IBM reports that C/2 and Macro Assembler/2 will be available initially for the Presentation Manager. Additional support for other languages will be provided over time. We likely will see implementations from other vendors as Presentation Manager arrives.

—*JA*

CALL FOR TECHNICAL TIPS

As befits a publication with a highly technical readership, *PC Tech Journal* has, since its inception, published a column of short solutions to technical problems under the title Tech Notebook. We have published some great ones in these pages, and we intend to continue and improve our service in this area. Along with the other changes made and planned for the magazine, we will be expanding this department under the new title Technical Tips, which will be brought together every month by technical editor Ted Mirecki. The new format will be more flexible, in part because each item will not be constrained to one page.

Readers are invited to submit their tips, provided they are solutions appropriate to the technical expertise of our audience. Illustrations by code fragments or *short* complete programs are welcome. Please send hard copy and disk files of both text and programs to the attention of Ted Mirecki at the *PC Tech Journal* offices (Suite 800, 10480 Little Patuxent Parkway, Columbia, MD 21044), identifying them as intended for the Technical Tips department. Text files may be in WordPerfect, Word, WordStar or plain ASCII format; source code must be plain ASCII ready for input to a compiler or assembler. Upon acceptance, payment will be made depending on length and content.

—JA

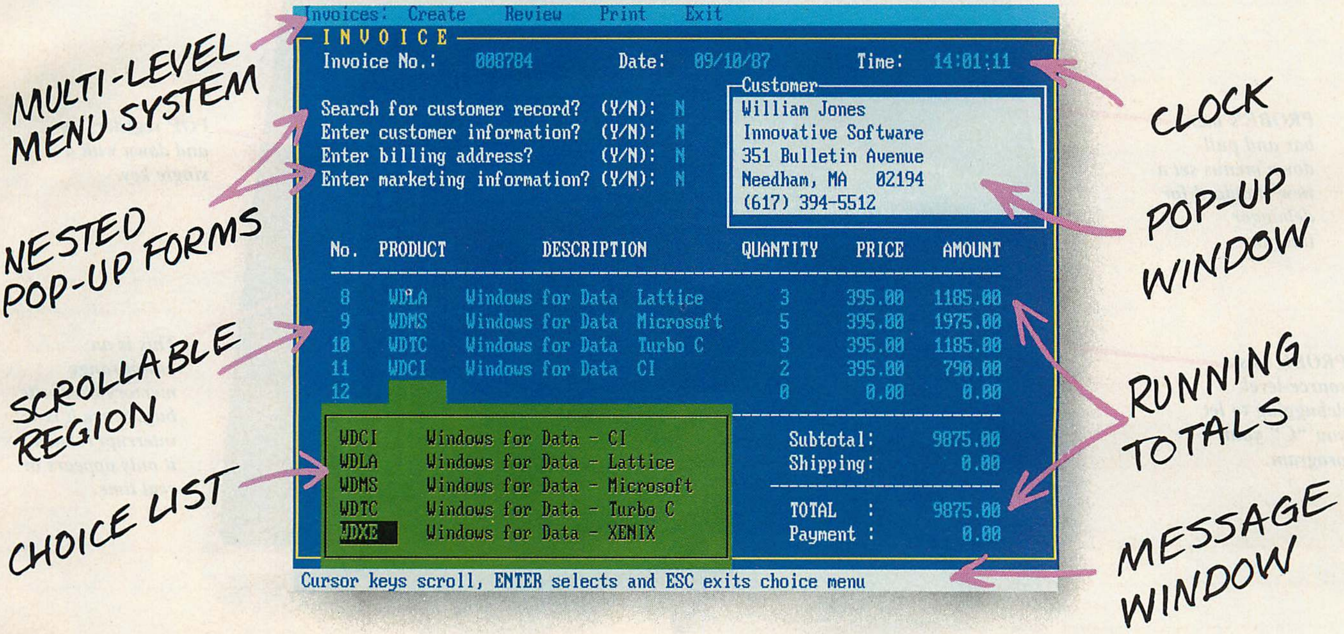
COMMENTS WELCOME

All letters to the editor should be directed to Editor, *PC Tech Journal*, Suite 800, 10480 Little Patuxent Parkway, Columbia, MD 21044. Correspondence also can be sumitted over MCI Mail to PCTECH.

Although *PC Tech Journal* cannot publish all letters received, every effort is made to answer as many as possible. Please keep letters brief and to the point, and include name, mailing address, and telephone number. When a letter is lengthy, a diskette is appreciated.

WINDOWS FOR DATA®

Uncommon Screens



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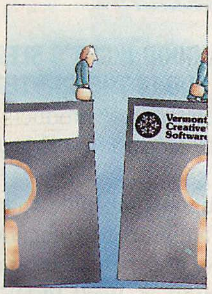

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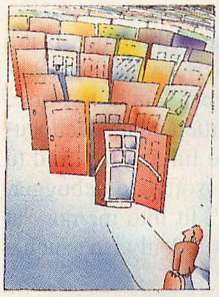

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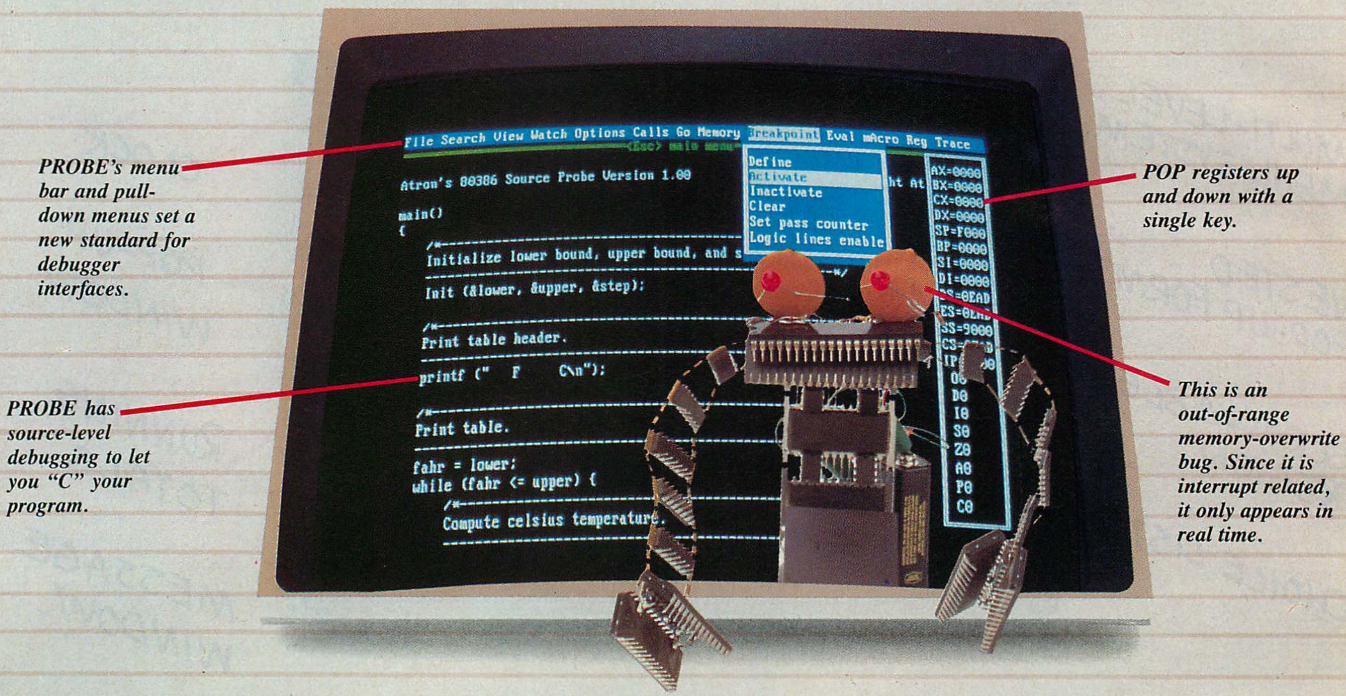

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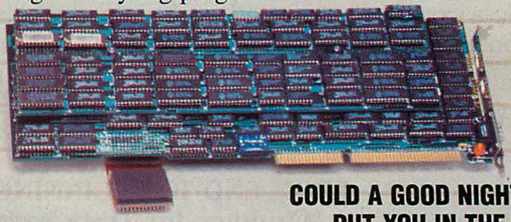

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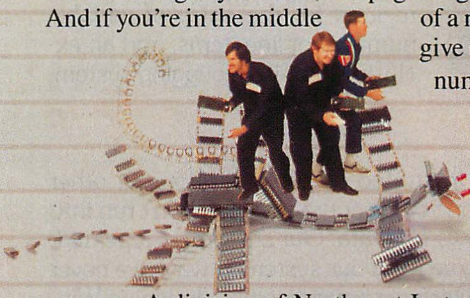

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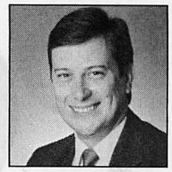


The OS/2 Debate

The new operating system will soon be upon us. What does it really mean?

OS/2, without question, is the fun topic of the year for debaters in the computer industry. On one side are those who are ready for the future, no matter what it holds or what it costs. On the other side are those wanting to get the most out of the existing installations of hardware and software and hold the line on development expense. The compromise position involves doing both. And, of course, there are many who just don't care, at least for the time being.

Here are two certainties about OS/2. First, interest in the new operating system is high. That is clear from reading the trade press, talking to developers and end users alike, and studying our own market research. Second, despite Microsoft's elaborate efforts to get the OS/2 story to everyone, confusion is rampant.

PC Tech Journal's own study, conducted in May by our research department, reflects both the interest and the confusion (76 percent of the respondents, drawn from a random sample of our subscribers, are systems professionals in end-user, consultant, or VAR/VAD companies, so they represent the key decision-makers where a new operating system is concerned). More than 69 percent of the respondents stated that they would purchase OS/2 when it becomes available, a hearty endorsement just one month after IBM's announcement. However, when asked if MS-DOS applications would be replaced with OS/2 versions, only 12 percent said yes, while 35 percent said probably. The majority said no, or probably not. Only 5 percent of the respondents had already started developing OS/2 applications. (See the accompanying sidebar, "Who's Converting to OS/2?")

Even though a healthy majority said they would buy OS/2, they don't know why. For example, most said that they desire the use of more than 640KB of memory, but applications written for MS-DOS do not automatically get that advantage in OS/2. A new OS/2 version of an application is therefore implicit, but that is a job the majority said it is not likely to tackle.

Increasing the confusion, 46 percent said they were considering other operating systems, the most popular being UNIX (77 percent), but Quantum's QNX, the Software Link's PC-MOS, and Quarterdeck's DESQview each scored an impressive 20 percent (multiple answers were allowed for this question). This widespread exploration of the alternatives may explain why so few have begun OS/2 development. Except for DESQview, consideration of other operating systems means that existing software will not be used for obvious compatibility reasons.

We also asked respondents to rate the importance of five OS/2 features: more than 640KB of memory, multitasking, graphical user interface, LAN interface, and the compatibility box. The ability to handle more than 640KB of memory won out as OS/2's most important benefit, with multitasking running a close second.

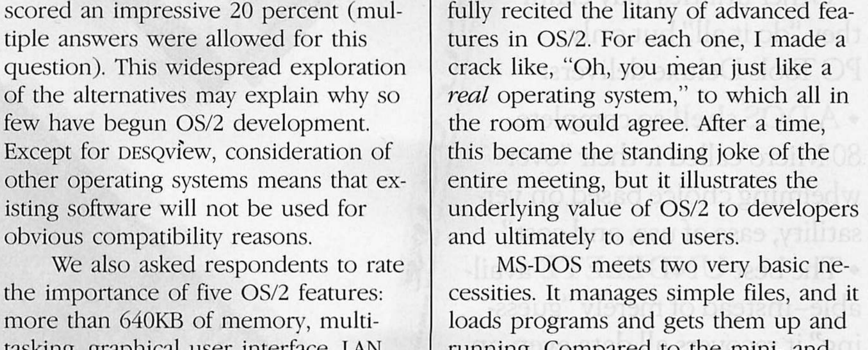
While support for more memory is a vital matter, our desire to build and use very large, memory-resident (or virtual) applications is exaggerated by years spent trying to cram 10-pound applications into the 1-pound MS-DOS box. Focusing on more memory tends to cloud other important features of the new operating system.

A "REAL" OS

When Microsoft first briefed editor Julie Anderson and me about OS/2, Steve Ballmer (vice president of systems software) and his managers carefully recited the litany of advanced features in OS/2. For each one, I made a crack like, "Oh, you mean just like a *real* operating system," to which all in the room would agree. After a time, this became the standing joke of the entire meeting, but it illustrates the underlying value of OS/2 to developers and ultimately to end users.

MS-DOS meets two very basic necessities. It manages simple files, and it loads programs and gets them up and running. Compared to the mini- and mainframe operating systems that most *PC Tech Journal* readers cut their teeth on—such as UNIX, VMS, or AOS—MS-DOS is a mere toy.

OS/2, on the other hand, is a direct descendant of such operating systems and therefore brings a large set of systems benefits to the environment of the desktop computer. Nevertheless,



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two pressing questions remain. What are all these features good for? And, how will the average user handle the increased complexity?

In casual conversation with users, I hear them talk about context switching and large programs. Users want all of their applications ready and available at the touch of a key. Although memory is somewhat hard to come by in MS-DOS, context switching is not; numerous programs are on the market today that provide this facility under MS-DOS. Actually, memory is available as well. The SHELL program in WordPerfect's Library, for example, can do wholesale swaps of applications to and from expanded memory. DESQview exploits expanded memory for multiple, resident applications and even provides concurrency (see "Protective Shells," Directions, October 1987, p. 9).

So, if the two most desired characteristics of an operating system are possible with add-ons to MS-DOS, why OS/2? Here are some reasons.

EXTENSIBLE STANDARDS

The most obvious benefit of an operating system with a large set of features is the convenience of a single environment. This leaves software developers in the comfortable position of having to develop only one version of their applications. Developers also become more efficient; support in the operating system for so many functions allows the developer to concentrate on the application instead of extensions to the system to facilitate the application, one of the main problems with MS-DOS.

No one could have predicted the vast number of extensions of so many different kinds that developers have made to MS-DOS over the years. Microsoft itself even made two: Windows and CD-ROM, not to mention the enhancements from version to version. Microsoft learned its lesson well, so OS/2 is built to be extensible. If the operating system support that your application needs cannot be derived from the kernel, you can add it yourself. These additions are not merely tied to the side of the system with baling wire, they are an integral part of it—indistinguishable from the operating system. That's how Microsoft and IBM will integrate products such as the LAN Manager and the Presentation Manager.

MULTITASKING

To begin to take advantage of all the available resources on your desktop computer, the operating system must allow more than one program to run simultaneously. This is supported in two ways in OS/2.

First, more than one program can be loaded and executed—for example, a C compiler and a text editor. In this classic case, the programmer writes or alters code while the compiler processes previously edited code in the background, using the large number of CPU cycles that live between the programmer's keystrokes—cycles that would otherwise lie fallow.

Second, a program (referred to as a *process* in OS/2) can kick off its own set of tasks (called *threads*) to perform a set of concurrent operations. For example, an OS/2-based data manager might spin off a thread to sort a file or allow two files to be sorted at the same time, one using CPU time while the other is waiting for disk I/O. The data manager might have its own separate work control task; interactive commands would be passed to the control task, which would decide how best to accomplish the work. This control task would kick off parallel tasks when appropriate and then queue up commands that had to be performed serially, all while you are conducting some other interactive business.

OS/2, in fact, has been optimized to support the process/thread model of multitasking, rather than provide efficient multiuser operation. Microsoft defines OS/2 as a single-user, multitask system, with emphasis on one user. That makes sense: if users were willing to forego their own, private execution unit (their personal computer), UNIX-based multiuser systems would be far more prevalent than they are today.

Given such a task-oriented computer, the possibilities are endless. Besides more efficiently handling the collection of jobs the user wants to perform interactively, OS/2 can provide sophisticated services that are able to compete as peers for system resources. A print spooler, for example, becomes just another program that accepts printing requests from other programs. The MS-DOS terminate-and-stay-resident (TSR) program, a kind of process without portfolio, becomes just another program. A 3270 terminal emulator is just another program. Of course, "just another program" in OS/2 means full access to files, communications, input devices, output devices, and those services performed by major subsystems, such as the LAN manager.

Another benefit of the task-orientation of OS/2 is that it does not require an interactive user. OS/2 can perform admirably as a network server and has the added advantage of being able to execute programs on the server that previously could run only on a workstation. So, for example, an OS/2-based server could be providing generic net-

WHO'S CONVERTING TO OS/2?

The ultimate value of OS/2 to an end user is its extensive set of internal features that enable software developers to deliver richer applications. That means developers themselves must be convinced of the value of the operating system before they commit their time, effort, and resources to conversion or development. The question to ask is: are developers moving to OS/2?

Based on *PC Tech Journal*'s questioning of vendors, the answer is a resounding yes. The typical response is similar to the one from Philippe Kahn, who allowed that his developers already had Borland's products running in OS/2. Timing of the release of OS/2 versions of the products is really the only question that is left unanswered.

A few vendors, such as Lotus, have made formal announcements about their plans. Lotus will convert 1-2-3 to OS/2 by way of version 3 of the product, a version which will also run under DOS 3.x. In addition, Lotus stated its intent to deliver a version that operates under the Presentation Manager, signaling a more serious commitment to the new environment. During my recent visit to Lotus headquarters in Cambridge, the company's managers made it clear that the new operating system presented many new opportunities for Lotus' products.

I have yet to speak with a software vendor who is not at least evaluating OS/2. Microsoft's OS/2 seminars are packed. Most vendors are already moving forward with a conversion plan, and some are working on new applications made possible by OS/2 support. Whatever the case, no one wants to be left on the sidelines. When OS/2 is finally available, everybody wants to be ready to play ball.

—*WF*

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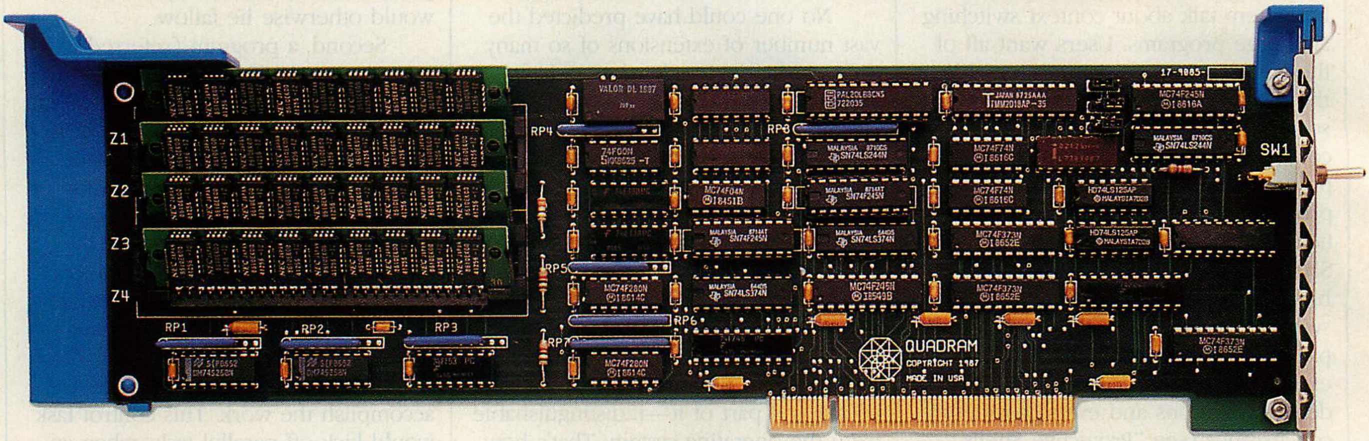

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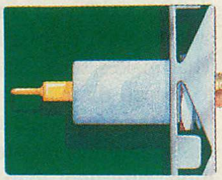

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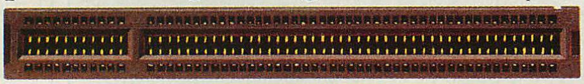

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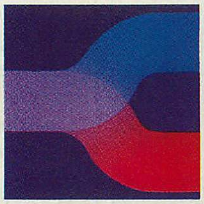

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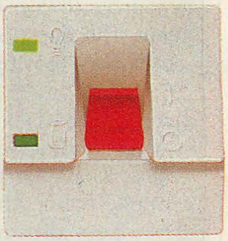

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work service at the same time it was running your favorite data manager in order to perform a piece of work more efficiently than it could have been done from the workstation.

INTERTASK COMMUNICATION

In multitasking, the tasks must be able to pass data or instructions between themselves. OS/2 provides facilities for task-to-task control and information passing, including all the traditional ones such as signals, semaphores, shared memory, pipes, and queues. These facilities allow tasks to coordinate their activity within the desktop.

OS/2 and the Microsoft LAN Manager offer an extension of the pipe feature, called *named pipes*, that allows a pipe to exist not just between two tasks in the same machine but between two tasks on *different machines*. This powerful capability is actually an enabling technology that allows smooth, cooperative processing between multiple machines, perhaps for such purposes as work-group computing. Given that a workstation program could command a program to load and run on a server, the named pipe can also provide a private communications link from the workstation to the server program.

REALTIME PROCESSING

The optimizations that make OS/2 a good multitask system also make it an interesting realtime system. OS/2's ability to support time-critical tasks and to eliminate the use of virtual memory (efficient realtime systems are usually memory-resident, or at least allow more direct control of virtual memory or overlays) makes it ideal for "less strenuous" realtime tasks, such as controlling point-of-sale devices in a department store; a strenuous task would be running the space shuttle.

In a sense, realtime capability is what a network server needs. The networking model is really nothing more than a message-passing system, where the messages that arrive at the server are requests for service and the messages sent back are responses to those requests. However, it is an extremely contentious environment. Each workstation expects response quickly, so the requests have to be interpreted and dispatched as rapidly as possible by the server software.

The significant advantage of OS/2 in the realtime world is that it will be able to run standard applications. I have already suggested the data manager scenario. In the retail setting, the new version of Lotus 1-2-3 could be brought up to take a snapshot of sales to the moment, while the selling floor continued to chug away. Extending this scenario is easy; direct tie-ins with off-the-shelf data managers, accounting systems, and communications software (for forwarding sales information to a central headquarters, for example) can save on development time (and thus reduce cost) and provide significant added value to the system.

With the proper hardware, an OS/2-equipped computer should be able to handle lab and factory floor automation with relative ease. I expect to see software and hardware for this market segment rather quickly once OS/2 is generally available.

THE DEVELOPER WINS

Ultimately, OS/2 benefits an end user by virtue of its more efficient use of the computing resource and its ability to improve throughput (even if the user's apparent interactive performance drops a bit). The end user also wins by being able to load many programs at the same time (programs that will no longer conflict with one another the way so many TSRs currently do) and to switch contexts rapidly.

OS/2 should reduce complexity for end-user and support groups alike. For example, getting an MS-DOS system up and running or just installing the newest application can be very trying—and it does not always work. OS/2 offers the promise of being more consistent and rational; its automatic installation procedures are much easier, and the use of applications within the environment is more consistent.

Although it is the end user who enjoys these advantages of OS/2, it is the application developer who gains the greatest benefit. Because so many facilities are built into the operating system, the developer's time will not be spent inventing proprietary solu-

COMPATIBILITY COFFIN

We in the press have said that it would be suicide for Microsoft and IBM to introduce an operating system for 80286- and 80386-based desktops that did not provide the ability to run "old" applications, those originally written for MS-DOS. This is probably true: a cold-turkey conversion to OS/2 could be painful without OS/2 versions of cherished utilities and programs.

In response, Microsoft has obliged with a facility called the "compatibility box" for running a single MS-DOS application. The goal was to allow the old application to run, while OS/2 programs ran in the background, and vice versa.

Now, I think that it is too bad that we insisted on the compatibility box. It is a complicated feature that consumed vast amounts of development time at Microsoft, time that could have been better spent getting the new operating system to market sooner. Even with that monumental effort and Microsoft's best intentions, the result is far from perfect because numerous programs will not run in the box, so a new OS/2 version will be required. In fact, one Microsoft program, Windows 1.0x, will not run (although Windows 2.0 will), and any program that has a similar intimate relationship with MS-DOS is in trouble.

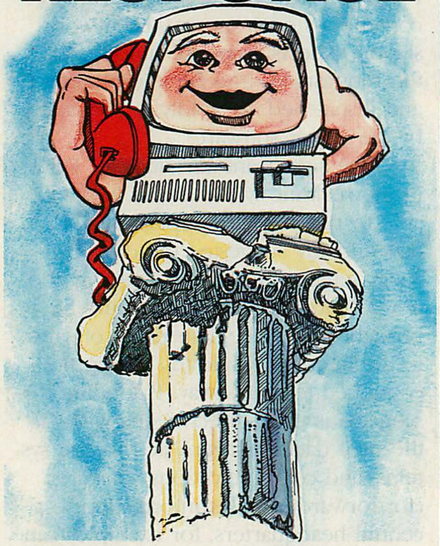
Moreover, the compatibility box does not offer as much memory as a real DOS machine. The code that makes the compatibility box work in OS/2 is bigger than MS-DOS itself, so very large programs will not even get loaded and programs with large, memory-resident data sets might not be able to load them. Expanded memory that adheres to the Lotus/Intel/Microsoft (LIM) specification *will* work, and that could help some of those programs that are faced with size problems.

The compatibility box does not meet the goal of total concurrency. Although OS/2 programs can run in the background while an old application is running, old applications are suspended when the instance of an OS/2 application has the focus (it is interacting with the user via the screen and keyboard).

The heaviest nail in the compatibility box's coffin is only now becoming visible. The tremendous acceptance of OS/2 by software vendors means that many programs will have equivalent OS/2 versions soon and even more compelling versions that take advantage of OS/2 features in the near future. So although the box provides a bridge between MS-DOS and OS/2, it is a bridge with a short (life) span.

—*WF*

DEVELOP VOICE RESPONSE



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tions. Furthermore, the developer is more likely to use the solutions that are provided in the base operating system, causing applications to handle similar functions in a similar way.

This benefit to the developer cannot be overstated. There is always some little system function that is not provided by MS-DOS that the application needs and that the developer must write from scratch. I have my own library of system functions, most of which directly interface with the BIOS. Dozens of library packages on the market today extend DOS to a more reasonable level; many more add complex features such as menus, windows, or graphics. All of these solutions have an identical flaw: changes from version to version of MS-DOS can introduce bugs into the library.

By providing so many more of these functions in the basic system and by extending the kernel cleanly, OS/2 eliminates a big chunk of work and a frustration at the development stage. Because the functions are part of the system, not tacked on, the operating system vendor must ensure that all functions are operating properly from version to version.

There's even more. The developer is an end user, too, so all the benefits that accrue to a user naturally work for the developer, often moreso because the developer is better able to configure and tune a system until the engine purrs. In effect, a user drives a PC like a sedan, while the developer drives it like a high-performance sports car.

LEAVING CONFUSION BEHIND

PC Tech Journal will surely research the OS/2 question again soon, because so many factors changes with time. The next time around, more user companies are sure to be engaged in development of OS/2 applications, and the issue of memory will be taken for granted, lessening its importance relative to other issues. The rush for OS/2 applications will be on, and interest in the compatibility box will be dwindling (see the sidebar, "Compatibility Coffin"). Interest in UNIX as an alternative to OS/2 is likely to fall off, and the new operating system will undoubtedly emerge on network servers.

I am equally confident that some creative, enlightened developer will conceive an application that is so striking, so compelling, and so dependent on the features of OS/2 that we will forget all these other complex matters of debate and rally to its side.

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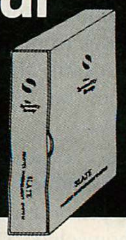

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NEW ARCHITECTURES, NEW STANDARDS

Desktop computers based on the 80386 chip are springing up everywhere. By the time you read this, almost all the compatible manufacturers should be shipping something with a 386 inside. Two companies, however, are doing more than just building AT clones with the bigger/better/faster microprocessor. AST Research and Compaq are advancing the state of the art with new machines embodying new system architectures (see the SYSTEMS section of Tech Releases, this issue, p. 29).

The new machines from both companies use the 20-MHz editions of the 80386 and the 80387. The resemblance ends there.

AST's Premium/386. AST Research has already produced a successful extension of the AT architecture in its Premium/286 (see "The Premium's Discount Premium" sidebar to Directions, October 1987, p. 9, and "Out from the Shadow of IBM: Premium/286," Steven Armbrust and Ted Forgeron, June 1987, p. 74). The Premium/286 extends the architecture of the AT by providing a special bus used primarily for memory, but that can also accommodate other devices, such as the recently announced 386 add-in board.

AST's Premium/386 represents another architectural departure from the AT standard, yet retains compatibility with the AT bus. AST has introduced arbitration to the bus by adding more signals and by designing slots incorporating the extension. Unlike AST's previous FASTslots, these new slots are completely AT compatible. Like Compaq's original Deskpro 386, the Premium/386 has a dedicated, 32-bit memory slot.

AST refers to the extended bus architecture as an "AT-compatible, arbitrated multimaster design." It is expected to go head-to-head with IBM's new Micro Channel architecture (see "An Architecture Redefined," David Methvin, August 1987, p. 58), but unlike IBM's new bus, the AST bus can accept existing adapter boards. New adapters that use the extended bus can gain control of the bus (that is, become a bus master) and thus directly access system resources, as well as establish a direct communications link with the CPU or other bus masters.

AST intends to provide its own set of adapters that exploit the arbitrated bus. The first will be a Bus Master Cache Disk Controller (ESDI) that will allow the Premium/386 to achieve higher disk performance than typical 386 systems. AST has suggested that graphics and communications are other good choices for the new bus because improved performance in those areas can significantly increase system throughput.

In keeping with its policy of offering high-performance machines at reasonable cost, AST's price for the 20-MHz Premium/386 with 40MB of hard disk is $5,600, or about $900 less than the 16-MHz Deskpro/386 and $1,400 less than the 16-MHz PS/2 Model 80-041. Although that price hardly knocks the mail-order cloners back on their heels, it is aggressive for equipment that is sold through full-support retail channels. For those reasons, the Premium/386 could become even more popular than the original Deskpro 386 for those who want to begin work in the 80386 world.

Compaq's Deskpro 386/20. Compaq took a different approach with its new Deskpro 386/20. In the tradition of its other Deskpro models, the I/O bus is compatible with the 8-MHz AT bus. No other changes or extensions were made. For Compaq, the trick is how the old I/O bus is connected to the processor.

In the AT architecture, the bus comes directly to the processor, which itself performs most of the control functions. Therefore, the transfer of data between the CPU and other system resources usually cannot be accomplished without the expense of many CPU cycles. Compaq has attempted to optimize CPU-related data transfer by providing a 32-bit bus connecting the 80386 processor, the 80387 math coprocessor, and cache memory. Operating at 20 MHz, the bus can sustain 40MB-per-second operation; cache memory is zero-wait-state.

This bus is managed by the Intel 82385 high performance 32-bit cache controller chip, which also manages both the AT-compatible, 8-MHz system I/O bus and the 20-MHz, 32-bit system RAM bus. The system memory uses less expensive RAM (than the cache, for example) and therefore incurs one wait state.

The use of the 82385, in what Compaq refers to as the Compaq Flexible Advanced Systems Architecture, allows the CPU to be all but isolated from data transfers that ordinarily would consume CPU time. A disk transfer, for example, could take place entirely between the I/O bus and the system RAM under control of the 82385. During that transfer, the CPU would normally be fetching instructions and data from cache memory. Compaq's use of the 82385 is so complete and sophisticated that data in cache memory are automatically updated if they change in system memory, because of input from the I/O channel.

The Compaq solution yields a machine that is entirely compatible with the PC and AT standard hardware and software, yet delivers striking performance approaching that of a dedicated workstation. Surprisingly, the 20-MHz Deskpro 386/20, with *60MB* of hard disk and a potential performance increment of 50 percent over the original Deskpro 386, is only $7,499 ($1,000 more than the Deskpro 386). It is also just $500 more than the IBM PS/2 Model 80-041 (40MB), but $1,000 *less* than the Model 80-071 (70MB); remember, those two IBM models are 16 MHz to boot. The 20-MHz PS/2 Model 80-111 (115MB) lists for $10,995; the comparable Compaq 386/20 (2MB RAM, 130MB disk) is $10,048, or about $950 less. The PS/2 models include the Video Graphics Array (VGA), so Compaq's advantage is somewhat lessened.

Both the AST and Compaq entries in the 386 sweepstakes compete directly with IBM's PS/2 line. Both companies have chosen to ignore the Micro Channel bus, at least for the moment, in favor of compatibility with an installed base of 10 million machines and its massive set of third-party options. At the same time, both machines exploit new technology and architecture to offer the user equipment that is both functional and capable.

Both machines will probably be so popular, however, that they will be in rather short supply.

—*WF*

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TECH RELEASES

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Compaq Deskpro 386/20 (left) and the Compaq Portable 386

SYSTEMS

A microcomputer based on the 20-MHz Intel 80386 has been introduced by **AST Research, Inc.** The **Premium/386** operates at one or zero wait states and features an AT-compatible multimaster bus, 1MB or 2MB standard 32-bit memory on the system board (expandable up to 13MB), support for a series of high-capacity disk drives, a high-speed ESDI bus master, two serial ports, one parallel port, support for the 80287 or 80387, switchless installation,

16-MHz Premium/386 from AST Research, Inc.

optional graphics support, and a keyboard speed select. **Model 40** comes with 1MB RAM and a full-height 40MB hard-disk drive. Other models feature 2MB RAM and increased hard-disk storage capacity. AST's multimaster bus is a shared memory architecture that improves overall performance by eliminating CPU involvement in data transfers and has an inherent ability to accommodate advanced coprocessor and multiprocessor architectures while providing compatibility with the current AT bus by using a high-speed, 32-bit data path from CPU to memory and using 16-bit data paths to provide AT compatibility. Model 40, $5,600; prices for other models are not yet available. *AST Research, Inc., 2121 Alton Avenue, Irvine, CA 92714-4992; 714/863-1333*

CIRCLE 302 ON READER SERVICE CARD

Combining the Intel 20-MHz 80386 using 32-bit architecture with the Intel 82385 cache-memory controller, **Compaq Computer Corporation**'s latest microcomputer entry, the **Deskpro 386/20**, provides performance enhancements unequaled by 16-MHz 80386-based systems. The Deskpro 386/20 is available in three models distinguished by storage capacity. **Model 60** includes 1MB of RAM with an additional 32KB of static RAM for cache memory, one high-performance 60MB hard-disk drive with an average access time of less than 30 ms, one 5.25-inch 1.2MB diskette drive, realtime clock, standard interfaces for parallel and asynchronous communications, and a socket for either a 20-MHz 80387 or an optional Weitek coprocessor board. Other standard features include a security keylock, Compaq Expanded Memory Manager (CEMM), a disk-caching utility, Compaq enhanced keyboard, and a 220-watt power supply. Available expansion slots include four 16-bit and two 8-bit slots. Room for up to four internal storage devices is included. **Model 130** includes all of the standard features of Model 60 but has a 130MB hard-disk drive (with an average access time of less than 20 ms). Model 130 only has room for three additional internal storage devices and has one less 16-bit slot available than Model 60. **Model 300** includes all of the features of Model 130 but increases the hard-disk drive capacity to 300MB. Model 60, $7,499; Model 130, $9,499; and Model 300, $12,499; 20-MHz 80387, $1,199; Weitek coprocessor board, $1,999.

Optional 40MB ($1,999) and 135MB ($1,999) internal tape backup systems (with data transfer rate of 1MB and 5MB per minute respectively) are available for the Deskpro 386/20.

A portable system incorporating the Intel 20-MHz 80386, the **Portable 386**, also was announced by Compaq. Standard features for both configurations include 1MB high-speed 32-bit RAM expandable internally to 10MB (the main system board can accommodate 2MB), a 5.25-inch 1.2MB diskette drive, a socket for a 20-MHz 80387, a high-resolution dual-mode plasma display, automatic 110V/220V line selecting feature, asynchronous communications, parallel and RGBI interfaces, and a realtime clock/calendar. Weighing only 20 pounds, **Model 40** features a 40MB hard-disk drive with an average access time of less than 30 ms. **Model 100** increases the disk capacity to 100MB (with an average access time of less than 25 ms), but only weighs one pound more than Model 40. Both models come standard with the Compaq portable enhanced keyboard, featuring a 91-key layout (including 12 programmable function keys and a 10-key numeric/cursor keypad) that is fully compatible with software written for standard enhanced keyboards. Model 40, $7,999; Model 100, $9,999.

An optional plug-on expansion unit ($199) that includes two full-size 16-bit slots is available. A 40MB hard-disk drive backup expansion unit ($999) that is attached to the back of the Portable 386 can be easily removed to be left behind or taken with the computer. The self-contained unit measures 9.8 by 16 by 7.8 inches. A 1MB 80-nanosecond RAM upgrade is $599. *Compaq Computer Corporation, 20555 FM 149, Houston, TX 77070; 713/370-0670*

CIRCLE 301 ON READER SERVICE CARD

From **IBM Corporation** comes the **IBM Personal System/2 Model 80-311**, a floor-standing system with a 20-MHz zero-wait-state 80386 that offers

80386-based Tandy 4000 personal computer

PC125Fi .25-inch tape drive from Cipher Data Products

more than two-and-one-half times the standard storage capacity of the Model 80-111 announced in April. The system features a 5.25-inch 314MB hard-disk drive with room for another 5.25-inch hard disk. Standard configuration includes 2MB RAM system board memory (which can be expanded to 4MB on the system board and maximum memory to 16MB with memory boards), a 3.5-inch 1.44MB diskette drive with another optional diskette drive, Micro Channel architecture, diskette controller, serial port, parallel port, keyboard/pointing-device ports, Video Graphics Array (VGA) on the system board, and seven available slots (four 16-bit and three 32-bit). $13,995. The **314MB Fixed Disk Drive Option** easily attaches to Models 80-071 and 80-111 without the need to use an expansion slot. $6,495.

A member of the PS/2 family for educational, home, and small-business use has been designed by IBM. The

IBM Personal System/2 Model 25 with space-saving keyboard

IBM Personal System/2 Model 25 operates at 8 MHz with zero wait states with an Intel 8086. Standard features include 512KB on system board (which can be upgraded to 640KB), 3.5-inch 720KB diskette drive, 64KB ROM containing power-on self-test (POST) of system components, BASIC language interpreter and BIOS support, diskette controller, serial and parallel ports, Multi-Color Graphics Array (MCGA) capability located on the system board, two expansion slots (one full size and one half size) and a choice of either the IBM space-saving keyboard (4.2 pounds, 16-by-7.5 inches) or, for an additional $45, the 101-key IBM enhanced keyboard. With 12-inch monochrome monitor, $1,395; with 12-inch color monitor, $1,695; 128KB system board memory expansion kit, $49.
IBM Corporation, Information Systems Group, 900 King Street, Rye Brook, NY 10573; 800/426-2468

CIRCLE 304 ON READER SERVICE CARD

Celebrating their tenth anniversary in the microcomputer industry, **Tandy Corporation** has unveiled four PC-compatible computers. The **Tandy 4000** personal computer features the Intel 80386 operating at 16 MHz, one 3.5-inch 1.44MB diskette drive, and four single in-line memory modules (SIMM) in the base configuration of 1MB. Eight application-specific integrated circuits (ASIC) are added for reliability. Standard configuration includes 1MB RAM expandable to 2MB on the main logic board using 256KB RAM modules or 8MB using 1MB RAM modules. The Tandy 4000 has two 8-bit and six 16-bit expansions slots. One dedicated 32-bit slot for memory expansion also is available. An optional 2MB memory expansion board brings maximum memory configuration up to 4MB using 256KB RAM modules or 16MB using 1MB RAM modules. Two drive slots accessible from the fromt panel accommodate the following storage options: 3.5-inch diskette drive (720KB or 1.44MB); 5.25-inch diskette drive (360KB or 1.2MB); 28-ms 40MB hard-disk drive; 65-ms 20MB hard-disk drive; 20MB internal disk cartridge system; and 40MB tape backup system. $2,599.

The **Tandy 3000HL**, an OS/2-ready, 16-bit computer, operates at a clock speed of 8 MHz, has one 5.25-inch 360KB diskette drive with two front drive slots to accommodate half-height internal drive options. Standard configuration includes 512KB RAM (expandable to 4MB), seven expansion slots (four 8-bit and three 16-bit), and a parallel port. $1,499.

The **Tandy 1000 TX** contains the Intel 80286 and a 3.5-inch diskette drive coupled with seven ASIC chips. A parallel printer port, RS-232C serial port, two joystick ports, three-voice sound, headphone jack, MS-DOS 3.2, GW-BASIC, and Radio Shack's Personal DeskMate software are all supplied. Standard configuration consists of 640KB of memory, one 3.5-inch 720 floppy drive and five 10-inch long, 8-bit expansion slots. $1,199.

The **Tandy 1400LT** is a battery-powered portable that uses the NEC V-20 operating at switchable clock speeds of 7.16 or 4.77 MHz. The portable is equipped with 768KB of RAM, two internal front-mounted 3.5-inch, 720KB disk drives, a back-lit supertwist LCD display, and a removable 12-volt battery pack (rated at 4 hour continuous use) or AC adapter. It weighs 13.5 pounds and has dimensions of 14.5 by 12.375 by 3.5 inches. $1,599.
Tandy Corporation, 1800 One Tandy Center, Fort Worth, TX 76102; 817/390-3700

CIRCLE 303 ON READER SERVICE CARD

PERIPHERALS

Two .25-inch tape systems for the IBM PC, PC/XT, PC/AT, and Personal System/2 have been introduced by **Cipher Data Products, Inc.** The **PC60Bi** (60MB) and **PC125Fi** (125MB) are half-height internal drives; both tape systems include mounting hardware, controller card, cable, software, and

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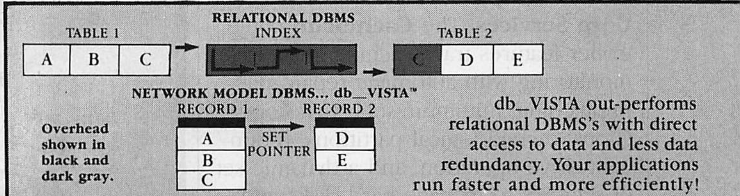

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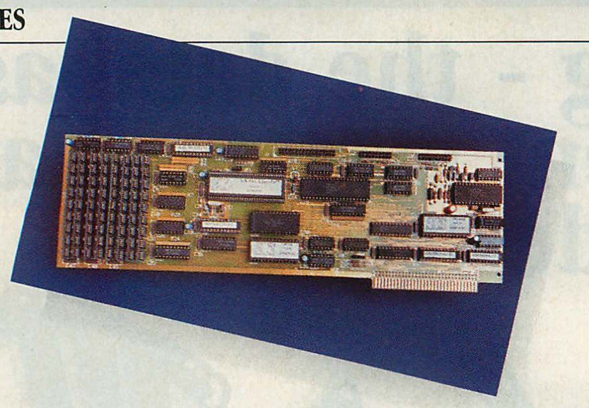
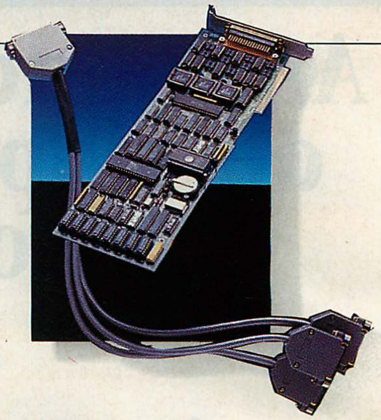


ScaanCorp Services, Inc.'s CacheRam controller boara



DATAGATE/LAN LAN-to-IBM gateway board from Wall Data

user documentation. The PC60Bi and PC125Fi systems support DOS, XENIX, and networks such as Novell's Ethernet and IBM's Token-Ring. A QIC-24 recording format with SYSTOS tape operating system provides compatibility with the IBM 6157 tape drive. The software allows users to backup systems on a selective file-by-file, partition, or entire-disk basis and offers other capabilities for backup, verification, and restoration of files. A timer system allows unattended backup. PC60Bi, $1,195; PC125Fi, $1,495.

Cipher Data Products, Inc., 10101 Old Grove Road, P.O. Box 85170, San Diego, CA 92138; 800/424-7437; 619/578-9100

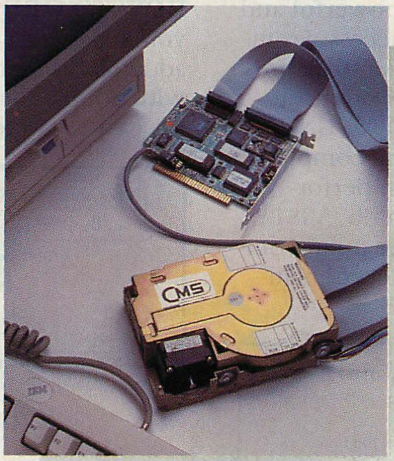
CIRCLE 312 ON READER SERVICE CARD

An intelligent hard-disk drive coprocessor card is available from **ScaanCorp Services**. The **CacheRam** controller features track caching, disk-drive monitoring with automatic repair, data prefetching, minimum-seek write operations, cached logical partitions, redundant drive operation, and a dynamic set of statistics to manage hard disks and monitor CacheRam controller activity. RLL encoding and 1KB physical sector size with one-to-one interleaving are included. Complete with a 6-MHz microprocessor, 512KB of cache memory (expandable to 8MB), a dual-channel DMA (direct memory access) controller, hard-disk BIOS, and an RLL hard-disk controller, this board is capable of controlling two high-capacity ST506/412 hard-disk drives. An automatic self healing (ASH) feature repairs grown defects in the hard-disk media. A ShadowDrive feature allows two identical hard-disk drives to be configured as a mirrored backup system. All data is written to both drives with no speed degradation to the host. If uncorrectable data is read from one drive, the data is immediately read from the redundant drive and returned to the host. The CacheRam controller will then repair or remap the faulty track using valid data read from the alternate disk drive. 512KB, $495.

ScaanCorp Services, 4241 N. Hall Street, Dallas, TX 75219; 214/520-7270

CIRCLE 313 ON READER SERVICE CARD

Mass-storage products for the IBM Personal System/2 Model 25 are being made by **CMS Enhancements, Inc.** The subsystems come in the following formatted capacities: **K20M25**, 20MB; **K30M25**, 30MB; **K40M25**, 40MB; and **K49M25**, 49MB. The 20MB and 40MB



K20M25 hard-disk subsystem from CMS Enhancements

units feature an 80-ms average access time and a data-transfer rate of 5 Mbps. The 30MB and 49MB units are have a 35-ms average access time and data-transfer rate of 7.5 Mbps. K20M25, $595; K30M25, $895; K40M25, $799; K49M25, $995.

CMS Enhancements, Inc., 1372 Valencia Ave., Tustin, CA 92680; 714/259-9555

CIRCLE 315 ON READER SERVICE CARD

A 32MB memory board has been developed by **Newer Technology** for the IBM PC/AT and Personal System/2 (PS/2). **CONCENTRATION** allows the user to increase memory capacity up to 32MB on a single expansion card without using piggyback boards. CONCENTRATION has backfill capabilities from 128KB without using any DIP switches. This memory board uses single in-line RAM modules (SINs) in either socketed or soldered versions. CONCENTRATION can be configured with either 256KB or 1MB chips and can operate at either 10 MHz with zero wait states or 16 MHz with one wait state. By changing the address, the user can take advantage of as much or as little expanded memory or virtual-disk memory concurrently as needed. CONCENTRATION has built-in parity checking and is available in standard AT or IBM PS/2 Micro Channel configurations. With 0KB installed, $399.

Newer Technology, 1117 S. Rock Road, Suite 4, Wichita, KS 67207; 316/685-4904

CIRCLE 311 ON READER SERVICE CARD

CONNECTIONS

A high-performance LAN-to-IBM gateway is being offered by **Wall Data, Inc.** The **DATAGATE/LAN** allows up to 32 PCs on a LAN to simultaneously conduct remote 3270 sessions with an IBM mainframe. DATAGATE/LAN is an intelligent card that fits into any PC slot. It has its own microprocessor with 256KB onboard memory, and gateway software to emulate remote IBM 3174/3274 cluster controllers. It supports NETBIOS-compatible LANs and communicates simultaneously with SNA and BSC hosts, allowing up to 128 sessions. Each PC on the LAN has up to seven active host sessions that can be allocated between terminal and printer emulation. Wall Data's workstation software includes IBM 3278/79 terminal emulation, 3287 printer emulation, high-speed file transfer, and unattended operation as

Continued on p. 41

Once again, Compaq raises the standard of performance for personal computers.

This time by a factor of two...

Introducing the two on earth

The new COMPAQ DESKPRO 386/20™

Last year, we introduced the COMPAQ DESKPRO 386,™ the most advanced personal computer in the world. Now the world has two new benchmarks from the leader in high-performance personal computing. The new 20-MHz COMPAQ DESKPRO 386/20 and the 20-lb., 20-MHz COMPAQ PORTABLE 386 deliver system performance that can rival minicomputers.* Plus they introduce advanced capabilities, without obsoleting your investment in software, hardware and training.

Our new computers employ an industry-standard 20-MHz 80386 microprocessor and sophisticated 32-bit architecture. But to make these two of the world's fastest PC's, we did more than just increase the clock speed.

For instance, both are built around a concurrent bus architecture. Two buses—one for memory and one for peripherals—eliminate information bottlenecks, allowing each component

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most powerful PC's and off.

and the new 20-MHz COMPAQ PORTABLE 386™

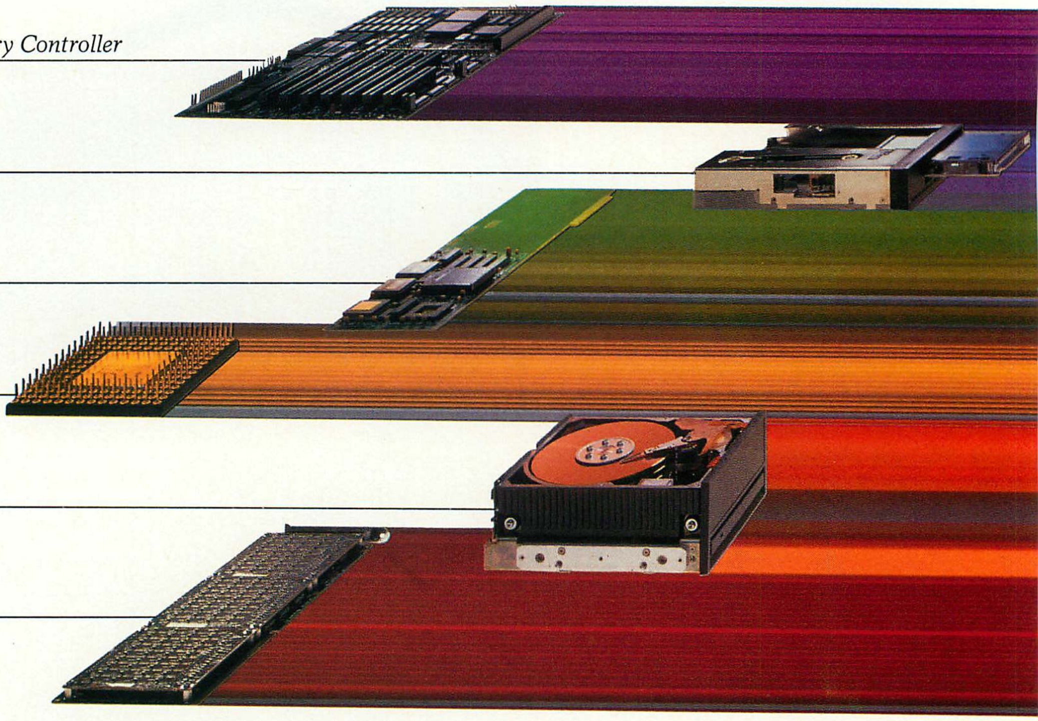
to run at its maximum speed. Together, they insure the highest system performance without sacrificing compatibility with industry-standard peripherals.

Both computers offer disk caching. Both offer the most memory and storage within their classes. Both let you run software being written to take advantage of 386 technology. And both run new MS-DOS®/BASIC Version 3.3 as published by Compaq. With it, our new portable and our new desktop can break the 32-megabyte limit on file sizes that handcuffs other PC's, allowing you to build files up to the size of your entire fixed disk drive.

And from now until December 31, 1987, both computers come with a free package of new Microsoft® Windows/386 Presentation Manager. It provides multitasking and switching capabilities with today's DOS applications to make you more productive. But that's just the beginning. To find out more, read on.

COMPAQ®

The question wasn't but how to get the



System Board with 20-MHz Cache Memory Controller

135-MB Tape Backup

Weitek Coprocessor Board

20-MHz 80386 processor

300-MB Fixed Disk Drive

16 MB of 32-bit RAM

The most powerful personal computer in the world

The COMPAQ DESKPRO 386/20 is an impressive 50% faster than 16-MHz 386-based personal computers. Even more impressive is the fact that it's up to 25% faster than other 20-MHz 386's. That's because the processor is just one small part of how the COMPAQ DESKPRO 386/20 outperforms every other PC in the world today and even many minicomputers.

The big reason is the new COMPAQ Flexible Advanced Systems Architecture, which optimizes overall system throughput while maintaining full compatibility with industry-standard peripherals. It does this by combining an advanced memory caching scheme with memory and peripheral buses that operate concurrently.

Complementing the speed of the microprocessor is the new advanced 20-MHz Intel® 82385 Cache Memory Controller. Like an efficient secretary that keeps frequently used information close at hand, it allows the microprocessor to operate at 0-wait states 95% of the time.

While one bus handles these high-speed operations, another *simultaneously* handles periph-

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how to get to 20 MHz, most out of 20 MHz.

erals operating at the industry-standard 8 MHz.

This flexible approach allows you to dramatically increase system throughput while preserving your investment in monitors, disk drives, and expansion boards. It can also accommodate today's and tomorrow's most advanced peripherals without constraining their performance.

Take options like our new Weitek™ Coprocessor Board. Never before offered in a PC, it can increase the speed of calculation-intensive, engineering and scientific applications by a factor of six, giving the COMPAQ DESKPRO 386/20 the performance of a dedicated engineering workstation at a fraction of the cost.

Compaq also provides 130- and 300-Megabyte Fixed Disk Drives with some of the industry's fastest access times. And when used with disk caching software, they represent the highest-performance storage subsystems available.

As for memory, Compaq offers 32-bit high-speed RAM. One full megabyte comes standard and is expandable to 16 megabytes without using an expansion slot. Plus, we included the COMPAQ Expanded Memory Manager. It supports the LIM standard so your software can break the 640-Kbyte barrier even before OS/2™ is released.

As tasks become more complex and users demand more advanced capabilities, Compaq responds by raising the standard of performance in personal computing.

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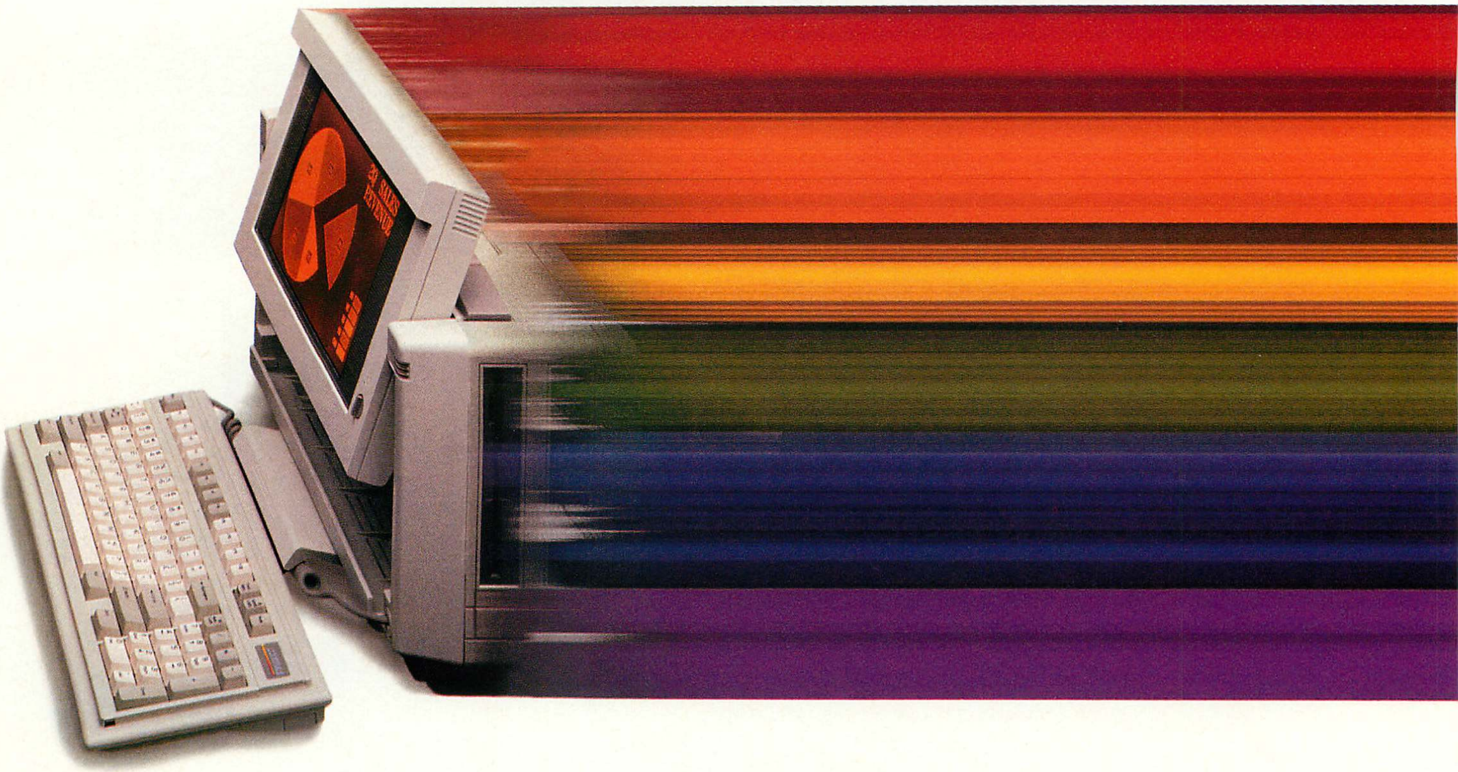
DESKPRO 386/20™

Everyone expected Compaq
But no one



Pound for pound, it is the world's most powerful computer

Compaq has long been recognized as the world leader in both 80386 technology and portable computing. So it isn't surprising that we would combine the two.

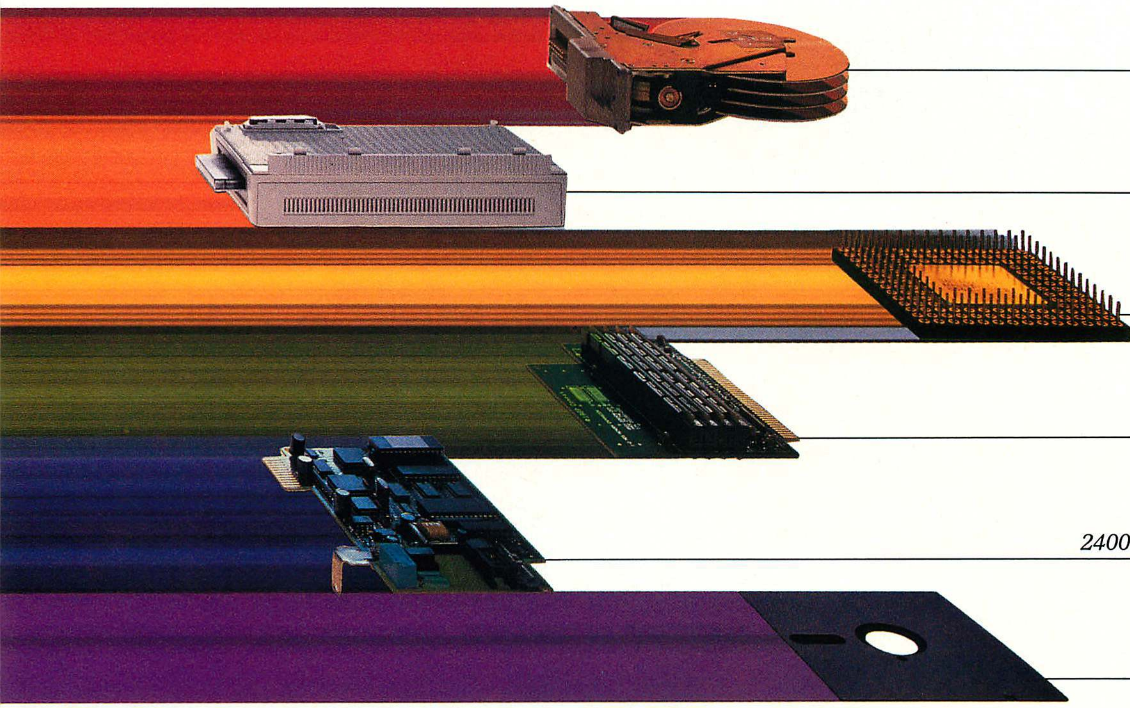
But no one expected the new COMPAQ PORTABLE 386 to run at 20 MHz. And no one even dreamed that it would offer 100 megabytes of storage, disk caching, and much, much more.

Our newest 20-lb. portable computer goes far beyond an 80386 microprocessor with a handle. It's not just the most advanced portable in the world. Pound for pound, it's the world's most powerful computer. Period.

Like the recent COMPAQ PORTABLE III,™ which changed the shape of full-function portable computing, the COMPAQ PORTABLE 386 makes no compromises. It offers more speed, memory, storage and features than any other portable PC. It runs your current software up to 25% faster than 16-MHz 386 PC's. Beyond that, its performance in calculation-intensive

It simply works better.

to introduce a 386 portable PC.
expected all this.



applications is increased even more when you add an optional 20-MHz 80387 coprocessor.

Memory? Get one megabyte of 32-bit, high-speed RAM standard or go as high as 10 MB internally. And like all of the COMPAQ 386-based PC's, it features the COMPAQ Expanded Memory Manager.

With our high-performance 100-megabyte internal fixed disk drive, you can actually fit 500 lbs. of data-filled pages into a 20-lb. PC, unsurpassed storage for a portable. If that's too much for you, we also offer a 40-megabyte model.

We've become famous for building desktop computer capabilities into our portables without leaving anything out. The COMPAQ PORTABLE 386 is more proof. It has a high-resolution, 640 × 400, 10-inch plasma display; a full-size, portable enhanced keyboard; two industry-standard expansion slots in a lightweight, optional plug-on unit; a choice between an optional 2400- or 1200-baud Hayes®-compatible modem; a full-size 5¼-inch 1.2-MB diskette drive; even an optional 40-MB tape backup.

These features, combined with the ultimate in portable performance, make the COMPAQ PORTABLE 386 the *biggest* PC this *small*.

COMPAQ

PORTABLE 386™

Compaq moves you ahead without leaving you behind.

Compaq offers the most complete line of high-performance 386 solutions. They all run industry-standard software and hardware, protecting the investments you've already made.

At the same time you won't be left behind when other technologies become important. Multitask with existing applications using Microsoft Windows/386 Presentation Manager. Add VGA graphics if you wish. Run OS/2 when it's available. And now 3½-inch drives are even an option for our desktops.

We optimize the most advanced technology while maintaining compatibility with the past, present and future. This makes COMPAQ PC's a wise decision for serious business users. Because at Compaq, we don't burn bridges, we build them.

See the COMPAQ DESKPRO 386/20 and COMPAQ PORTABLE 386 at an Authorized COMPAQ Computer Dealer. *And from now through December 31, 1987, get Microsoft Windows/386 Presentation Manager* _free_ *when you buy a 386-based COMPAQ computer.* For more information, call 1-800-231-0900, Operator 40. In Canada, call 416-733-7876, Operator 40.

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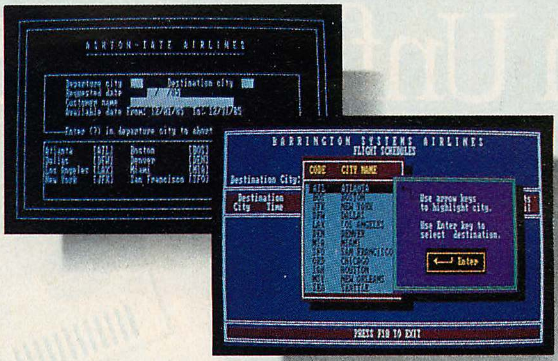
It simply works better.

LifeServer 386, Univation's network server



Clarion generated screen (front) using an unaltered dBASE III file (rear)

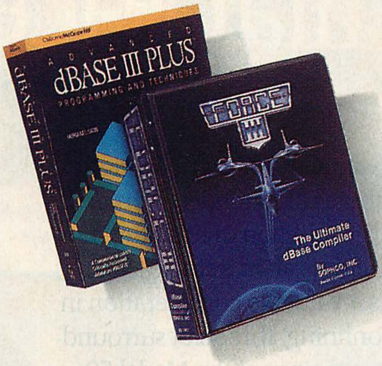
standard features. Prices range from $1,995 for 32 host sessions with one host link to $3,495 for 128 host sessions with two host links.
Wall Data Inc., 17769 N.E. 78th Place, Redmond, WA 98052-4992; 800/433-3388; 206/883-4777
CIRCLE 310 ON READER SERVICE CARD

A network server based on 32-bit 16-MHz 80386 technology is available from **Univation, Inc.** The **LifeServer 386** network server comes bundled with Univation's LifeNet LAN operating system. LifeNet combines file server and database server software, processing index at the network server, instead of at the workstation. LifeServer 386 includes eight I/O expansion slots (one 8-bit, five 16-bit, and two 32-bit slots), one serial port, and one parallel port. Hard-disk capacity for the server ranges from 40MB to 320MB. Two diskette drives, one streaming-tape cassette and two hard disk drives are available. LifeServer 386 basic server, $4,600; with 2MB RAM, 60MB tape drive, and 75MB hard disk, $10,595; with 2MB RAM, 60MB tape drive, and 140MB hard disk, $14,195.
Univation Inc., 1231 California Circle, Milpitas, CA 95035; 800/221-5842; 408/263-1200
CIRCLE 308 ON READER SERVICE CARD

DATABASE MANAGEMENT

A professional programming tool for dBASE programmers, **dBFind version 2.0** is being offered by the **Software Development Factory**. Version 2.0 finds real syntax errors in dBASE programs, not just mismatched IF and ENDIF control structures. It generates a single- and cross-module cross reference of variables, including the type of each reference. The dBFind programming tool runs inside dBASE, so the programmer does not have to exit dBASE to find syntax errors. Version 2.0 supports Clipper extensions and checks the number of arguments to built-in dBASE and Clipper functions. $99.
Software Development Factory, 400 E. Pratt Street, Suite 800, Baltimore, MD 21202; 301/666-8129
CIRCLE 317 ON READER SERVICE CARD

A compiler designed for dBASE-type programs has been introduced by **Sophco, Inc.** The **FORCE III** compiler is written in 80X86 assembly language and supports standard dBASE commands. It features arrays, FOR . . . NEXT loops, sound, extended math functions, I/O directive capability, file primitives (such as FOPEN and FREAD),



FORCE III dBASE compiler (front) by Sophco, Inc.

and new numeric data types. FORCE III automatically takes advantage of an on-board math coprocessor when present. It comes with complete documentation and the 850-page dBASE reference book, *Advanced dBASE III PLUS Programming and Techniques*, by Miriam Liskin (Osborne/McGraw-Hill). $129.
Sophco, Inc., P.O. Box 7430, Boulder, CO 80306-7430; 800/922-3001; 303/444-1542
CIRCLE 319 ON READER SERVICE CARD

A software bridge has been unveiled by **Barrington Systems, Inc.** that provides dBASE III users with an easy migration path to Barrington's **Clarion** application development environment, while retaining file compatibility with existing dBASE programs. Called the **Data Base Three LEM** (Language Extension Module), it provides the capability of reading and writing dBASE III files with Clarion application programs. The LEM provides file-processing commands for .DBF files that parallel Clarion file-processing commands. Record keys can be the same as those used in dBASE III programs or unique to the Clarion-written application. Indexes are updated and maintained by the Clarion program during processing; they are valid for subsequent processing by .PRG programs. The Data Base Three LEM, $49.50; Clarion, $395.00.
Barrington Systems, Inc., 150 E. Sample Road, Pompano Beach, FL 33064; 800/354-5444; 305/785-4555
CIRCLE 318 ON READER SERVICE CARD

The first codevelopment project between **Ansa Software** and **Borland International** following their proposed merger has been announced. **Version 2.01** of Ansa's multi- and single-user database program, **Paradox**, includes Borland's **EMS Driver**. The addition of the EMS Driver allows a Paradox user in the single-user environment to take full advantage of the expanded memory capabilities offered by the IBM Personal System/2 Models 50 and 60. By accommodating the Lotus/Intel/Microsoft expanded memory specification (LIM EMS) on the IBM 286 Memory Expansion Option board, Borland's software driver adds up to 2MB of memory per board, or up to 8MB per system for PS/2s. Free upgrade from 2.0; upgrade from 1.1, $195.
Ansa Software, 1301 Shoreway Road, Belmont, CA 94002; 415/595-4851
CIRCLE 320 ON READER SERVICE CARD
Borland International 4585, Scotts Valley, CA 95066; 408/438-8400
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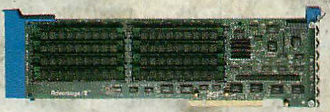

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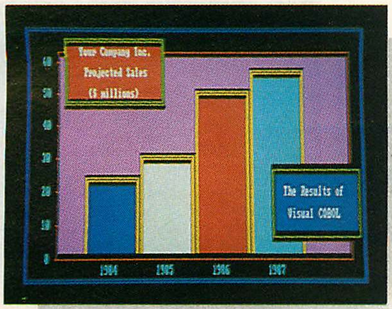
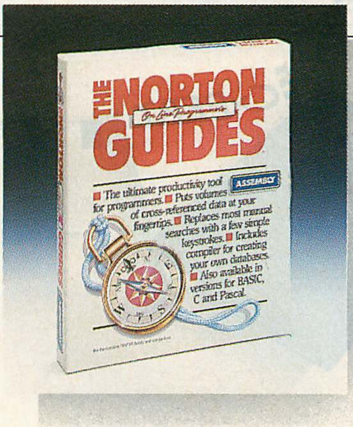
CIRCLE NO. 199 ON READER SERVICE CARD



Screen shot of mbp Software's Visual COBOL-85



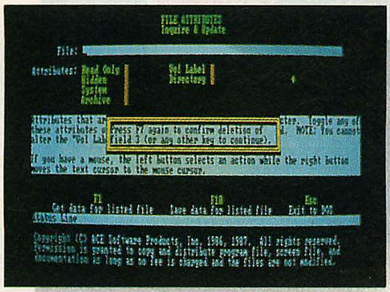
The Norton On Line Programmer's Guides for assembly language

SOFTWARE DEVELOPMENT

An **EMS Driver** for the IBM Personal System/2 Models 50 and 60 is being licensed to OEMs and software developers by **Borland International**. With the software driver, licensees can accommodate the Lotus/Intel/Microsoft expanded memory specification (LIM EMS) on IBM's 286 Memory Expansion Option, a memory board that adds up to 2MB of memory per board for the PS/2. Borland's EMS Driver takes advantage of the unpublished bank-switching capability of IBM's expansion option to deliver high-performance, high-speed memory management. Borland will include the EMS driver with many of its products, including SideKick Plus, Reflex: The Database Manager, and EMS Toolbox. The EMS Driver also includes an EMS RAM disk, printer spooler, and a quick set-up program. (See the related announcement involving Ansa Software's Paradox 2.01 in the DATABASE MANAGEMENT section, p. 41.)
Borland International, 4585 Scotts Valley Drive, Scotts Valley, CA 95066; 408/438-8400
CIRCLE 322 ON READER SERVICE CARD

From **mbp Software and Systems Technology, Inc.** comes the release of **Visual COBOL-85**, a native-code COBOL compiler for the IBM PC based on the ANSI COBOL-85 standard. The heart of Visual COBOL-85 is an integrated screen management system (SMS) that eliminates much of the coding that is normally required to generate screens. Some highlights of the SMS are automatic line and box drawing, foreground and background color support, pull-down menus, user-selectable character attributes, and unlimited windowing capability. Visual COBOL-85 supports Intel's large memory model for object code, allowing programmers to take advantage of the maximum 640KB of user memory under DOS. Other features included are a multi-keyed ISAM facility, an interface to Microsoft C 4.0, GSA certification, and a SHRINK utility that reduces the storage requirements of .EXE files by more than 50 percent. $1,295.
mbp Software and Systems Technology, Inc., 1131 Harbor Bay Parkway, Suite 260, Alameda, CA 94501-6540; 800/231-6342; 415/769-5333
CIRCLE 331 ON READER SERVICE CARD

Release 3.0 of the **SCREEN-ACE** form master for APL, C, and Assembly language on the IBM PC and PS/2 families of computers is available from **ACE Software Products, Inc.** The Form Master is designed to create and maintain forms, tables, text screens, and menus. The programmer is allowed to tailor the user interface to the needs of the application. Some new features in this release include mouse support, keyboard remapping and redefinition, support for extended keyboards, an enhanced screen builder, pop-up windows (both tiled and overlaid), data validation, new field types, and graphic mode support. It is also compatible with DESQview, TopView, and Windows. The IBM PS/2 Models 30, 50, 60 and 80 are supported using OS/2 (in compatibility mode) or DOS 3.3. VGA, MCGA, EGA, CGA, and MDA are fully supported. Included with SCREEN-ACE is a demonstration diskette. SCREEN-ACE 3.0, $195; demo disk alone, $3.



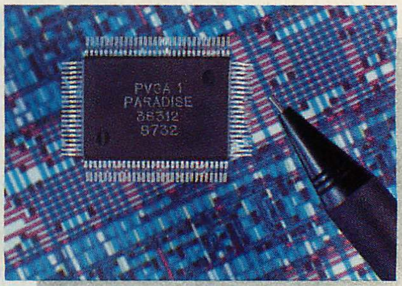
Screen shot of ACE Software's SCREEN ACE 3.0 form master

ACE Software Products, Inc., Product Sales and Support, 6934 Petit Avenue, Van Nuys, CA 91406; 818/989-5329
CIRCLE 329 ON READER SERVICE CARD

Peter Norton Computing, Inc. has released **The Norton On Line Programmer's Guides**. Available in four languages, C, Assembly, Pascal, and BASIC, this new software program is an on-line language reference database system for programmers. Language syntax, data types, library functions, ASCII characters, error messages, keyboard scan codes, and more can be instantly accessed while running any other program. The core of the Norton Guides is the Instant Access Program, which is RAM resident and uses about 65KB of memory. The Access Program can be purchased by itself, or with a Reference Database package. Additional Reference Database packages may be purchased separately to run on the Access Program. The Norton Guides can run in a conventional memory-resident mode (where the Norton Guides are loaded at start-up time—before applications are run), or a pass-through, memory-resident mode (the Norton Guides are invoked on the same DOS command line and are automatically uninstalled when the application ends). The Norton Guide's reference compiler has been included for the user to create their own Reference Databases complete with pull-down menus and expandable entries. Instant Access Program and one language database, $100; subsequent databases, $50 each.
Peter Norton Computing, Inc., 2210 Wilshire Blvd., Suite 186, Santa Monica, CA 90403-5784; 213/453-2361
CIRCLE 335 ON READER SERVICE CARD

An advanced virtual memory product, **VMEM**, has been announced by **Softools Software**. VMEM is a multipurpose vir-

CxPERT expert system building tool from Software Plus, Ltd.



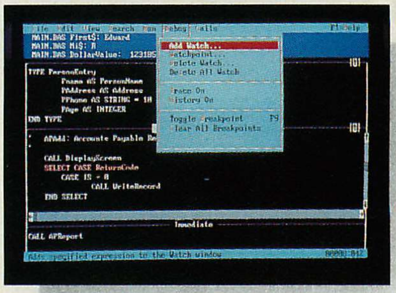
PVGA1 video controller chip from Paradise Systems

tual memory manager for C programs running in a DOS environment. Its features include memory usage that can be adjusted at runtime for 2KB to all available core, dynamic expansion at runtime, user-selectable page size, memory locking for frequently used data, data elements not limited in size or alignment, least recently used page replacement strategy, fast insertion and deletion at arbitrary locations, multiple virtual buffers open concurrently, and the design guarantees maximum speed and efficiency. $289.
Softools Software, 5245 E. Larkspur Drive, Scottsdale, AZ 85254; 602/996-3110
CIRCLE 330 ON READER SERVICE CARD

A software development tool for building expert systems in C has been announced by **Software Plus, Ltd.** Called **CxPERT**, it fully integrates expert systems technology into the C programming environment. CxPERT supports backward and forward chaining. CxPERT knowledge representation methods include attribute value pairs, frames, arrays of frames, and rules. CxPERT supports hierarchical inheritance and multiple inheritance. Other features include explanation, why, and logging facilities. Single PC license, $295; source-code license for other environments, $2,250; object-code site license, $650; combination tutorial/demonstration diskette, $10.
Software Plus Ltd., 1653 Albemarle Drive, Crofton, MD 21114; 301/261-0264
CIRCLE 333 ON READER SERVICE CARD

An enhanced version of the **Microsoft Macro Assembler** has been released by **Microsoft Corporation**. **Version 5.0** is considerably faster than previous versions and supports both the 80386 and 80387. Macro Assembler also is easier to use than previous versions and includes Microsoft's source-level debugger, CodeView. Like Microsoft Windows 2.0, CodeView's user interface makes debugging easy by allowing observation of the program through multiple windows as the program executes. Completely rewritten documentation includes a special guide for mixed-language programming. Other enhancements include faster linking, DOS interface macros, larger program capacity, and additional environment variables and command-line options. Version 5.0, $150: upgrade from 4.0, $40; upgrade from earlier versions, $75.

Also released was an enhanced version of Microsoft's **QuickBASIC** that boasts compile speeds of up to 150,000 per minute, program modification and debugging without recompilation, and an editor that checks syntax as you type, and instantaneous command test-



Microsoft QuickBASIC 4.0 debugging menu screen

ing. **Version 4.0** comes fully integrated with a subset of Microsoft's CodeView debugger, offers multiple module programming support, many enhancements to the BASIC language, and a multifile/multiwindow editor that supports MicroPro's WordStar commands. Microsoft has added binary file I/O capability for easier interface to business application software such as Lotus 1-2-3 and Ashton-Tate's dBASE III. $99.
Microsoft Corporation, 16011 NE 36th Way, P.O. Box 97017, Redmond, WA 98073-9717; 206/882-8080
CIRCLE 328 ON READER SERVICE CARD

TECHNOLOGY

Specifications on the **PVGA1**, a single-chip video controller that provides hardware and software-level compatibility with IBM's VGA display standard, have been released by **Paradise Systems, Inc.** It provides up to 640-by-480 pixel resolution, displays 16 colors out of a palette of 262,144, and also supports MCGA, EGA, CGA, and MDA display standards. PVGA1 has an 8- or 16-bit data bus for increased speed over the 8-bit data bus on IBM's VGA chip and has a 40-MHz maximum dot clock that allows it to display higher resolutions than 640 by 480 pixels. The chip is a 1.5 micron, 12,000 gate CMOS. In OEM 100-unit quantities, $60.
Paradise Systems, Inc., 217 E. Grand Avenue, South San Francisco, CA 94080; 415/588-6000
CIRCLE 306 ON READER SERVICE CARD

The **ET3000** VLSI chip from **Tseng Laboratories, Inc.** provides register-level hardware and software compatibility with IBM's VGA on a single chip. ET3000 features resolutions of 800-by-600, 720-by-512, 720-by-400, and 640-by-480 pixels, a high definition 132-column mode, 256 colors that can be selected from a palette of 256,000, downward compatibility with other IBM graphics standards, ultra-high resolutions of 1,024 by 768 pixels (with 16 colors from a palette of 256,000), interlaced and noninterlaced scan mode, color and monochrome text modes, and external digital-to-analog interface. In OEM quantities, $45 each.
Tseng Laboratories, Inc., 10 Pheasant Run, Newton, PA 18940; 215/968-0502
CIRCLE 307 ON READER SERVICE CARD

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C TOOLS PLUS/5.0
List $129 Ours $99

C TOOLS PLUS/5.0 is a library for Microsoft C that can provide you with a full spectrum of general-purpose utility functions. Included are functions that take advantage of the machine features of IBM-compatible personal computers and DOS and complement the standard compiler library. Almost all functions are written in C using techniques most suitable for good C program design. Some of the areas covered are: extensive string handling; screen handling including support for multiple monitors and the EGA; general utility and keyboard functions; DOS memory management; windows that can be stacked, removed and accept user input; intervention code; and interrupt service routine support for truly flexible resident applications. C TOOLS PLUS/5.0 includes all source code, complete examples and a comprehensive reference manual.

Supports Microsoft C 5.0 and Microsoft QuickC.

ESP
Command Plus
List $80 Ours $69

Command Plus is a powerful, bootable MS-DOS command processor fully compatible with COMMAND.COM. Many new features are included that will help you increase your speed, productivity and ease of programming. These include a history processor that lets you recall and edit previously entered commands using the cursor keys. The alias facility allows the creation of command macros with replaceable parameters. Other features include: regular expressions in filenames; directory and argument stacks; a command line editor; access to environment variables; a MOVE command; and Browse, a full screen file viewer. Command Plus also includes SCRIPT, a batch processor that uses a Pascal-like language that features: integer and string variables; boolean, math and string operators; CALL, FOR/WHILE, GOTO, IF/THEN/ELSE, and SWITCH statements; and display and file access routines. Enhancements to DIR include sort options and file attrib display. COPY options include selection by date/time range, and recursive sub-directory processing.

Requires 48K memory. Version 1.2.

Meridian Software
AdaVantage Compiler 2.0
List $795 Ours $735

The Meridian AdaVantage Compiler is a fully validated implementation of the Ada language. The compiler generates native 8086 code in the Intel standard object format. A linker is provided to create stand-alone executable files for MS-DOS. The Meridian AdaVantage Compiler package includes the compiler, linker, library management tools, support packages, runtime libraries and a configuration tool. In addition to the standard Ada packages, support packages are provided to make integer, floating point and text I/O more convenient to implement. The compiler also provides a pragma INTERFACE used to make calls to subprograms written in 8086 assembly language, Meridian C or Meridian Pascal. A source level debugger will be available in late 1987.

Requires hard disk and 640K memory. Runtime fees apply if more than 99 copies are sold. Version 2.0.

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EXSYS Runtime System	600	469
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Logic-Line Series All varieties by Thunderstone	CALL	CALL

ai - lisp language

Golden Common LISP by Gold Hill	495	CALL
Golden Common LISP Developer by Gold Hill	1190	CALL
Q'Nial Various by NIAL Systems	CALL	CALL
Star Sapphire LISP Compiler by Sapiens — New	495	429
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ai - prolog language

Arity Combination Package	1095	979
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PROLOG Compiler & Interpreter	650	569
Screen Design Toolkit	50	44
SQL Development Package	295	229
Arity PROLOG Interpreter	295	229
Arity Standard Prolog	95	77
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MPROLOG P500 by LOGICWARE	495	395
MPROLOG P550 w/Primer by LOGICWARE	220	175
Turbo PROLOG by Borland Intl	100	64
Turbo PROLOG Toolbox by Borland Intl	100	64

ai - smalltalk language

Smalltalk/V	100	84
EGA/VGA Color Option	50	45
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ai - texas instruments

Arborist Decision Tree Software	595	519
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Personal Consultant Easy — New Version	495	435
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Personal Consultant Runtime	95	84

ada language

AdaVantage GSA-Validated by Meridian Software	795	735
ADA Utility Packages	50	47
DOS Environment Package	50	47
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Janus/ADA D Pak by R&R Software	1250	1059
Janus/ADA ED Pak by R&R Software	395	349

apl language

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APL*PLUS PC Spreadsheet Mgr by STSC	195	139
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assembly language

386 ASM/LINK Cross Asm by Phar Lap	495	389
8088 Assembler w/Z-80 Translator by 2500 AD	100	89
ASMLIB Function Library by BCSoft	149	125
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Microsoft Macro Assembler	150	93
Turbo Debugger by Speedware	89	79
Turbo Editasm by Speedware	99	84
Visible Computer: 8088 by Software Masters	80	64

basic language

db/Lib for QuickBASIC by AJS Publishing	139	119
Finally by Komputerwerk	99	85
MACH 2 by Micro Help	69	55
Microsoft QuickBASIC	99	63
QBase Relational Database by Crescent	89	79
Quick-Tools by BCSoft	130	109
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True Basic w/Run-time — Special Price	200	99
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Eco-C Complete System by Ecosoft	140	119
Instant C by Rational Systems	495	369
Instant-C/16M by Rational Systems — New	895	695
Lattice C Compiler vers. 3.2 from Lattice	500	265
Mark Williams Let's C w/csd	75	54
Microsoft C Compiler w/CodeView — New Version	450	269
Microsoft QuickC Compiler — New	99	63
Optimum-C by Datalight	139	95
Turbo C Compiler by Borland	100	64
Uniware 68000/10/20 Cross Compiler by SDS	995	829

c interpreters

C-terp by Gimpel, Specify compiler	298	219
C Trainer with Book by Catalytix	122	87
Introducing C by Computer Innovations	125	99
Run/C by Age of Reason	120	69
Run/C Professional by Age of Reason	250	145

c utilities

Blackstar C Library by Sterling Castle — New	125	98
C++ by Guidelines w/version 1.1 kernel	195	172
c-tree & r-tree Combo by FairCom	650	519
c-tree ISAM File Manager	395	315
r-tree Report Generator	295	239
Csharp Realtime Toolkit by Systems Guild	600	489
Curses Window Dev Pkg by Aspen Scientific — New	119	105
with Source Code	289	249
dBx dBASE to C Translator by Desktop AI	350	299
with Source Code	550	419
Flash-up Windows by Software Bottling	90	78
GraphiC Color version by Sci Endeavors	350	274
GRAFLIB by Sutrasoft	175	159
HALO Graphics by Media Cybernetics	300	205
HALO Development Pkg for Microsoft	595	389
The HAMMER by OES Systems	195	129
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cobol language

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RealCICS	995	783
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debuggers & profilers

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Codesmith-86 by Visual Age	145	98
DSD87 by Soft Advances	125	79
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Periscope I with Board by Periscope	345	275
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Periscope II-X Software only	145	105
Periscope III 8 MHz version	995	795
Periscope III 10 MHz version	1095	875
The PROFILER with Source Code by DWB	125	89
TURBOsmith Source debugger for Turbo Pascal	99	89
The WATCHER Profiler by Stony Brook	60	51

disk utilities

Back-It by Gazelle Systems — New Version	130	115
Disk Optimizer by Softlogic Systems	60	55
Disk Technician by Prime Solutions — New	100	89
FASTBACK by 5th Generation Systems	179	129
Vcache by Golden Bow Systems	50	47
Vopt by Golden Bow Systems	50	47
Vfeature by Golden Bow Systems	80	74
Vfeature Deluxe by Golden Bow Systems	120	111
XenoCopy-PC by XenoSoft	80	69

dos utilities

Advanced Norton Utilities	150	99
Command Plus by ESP Software	80	69
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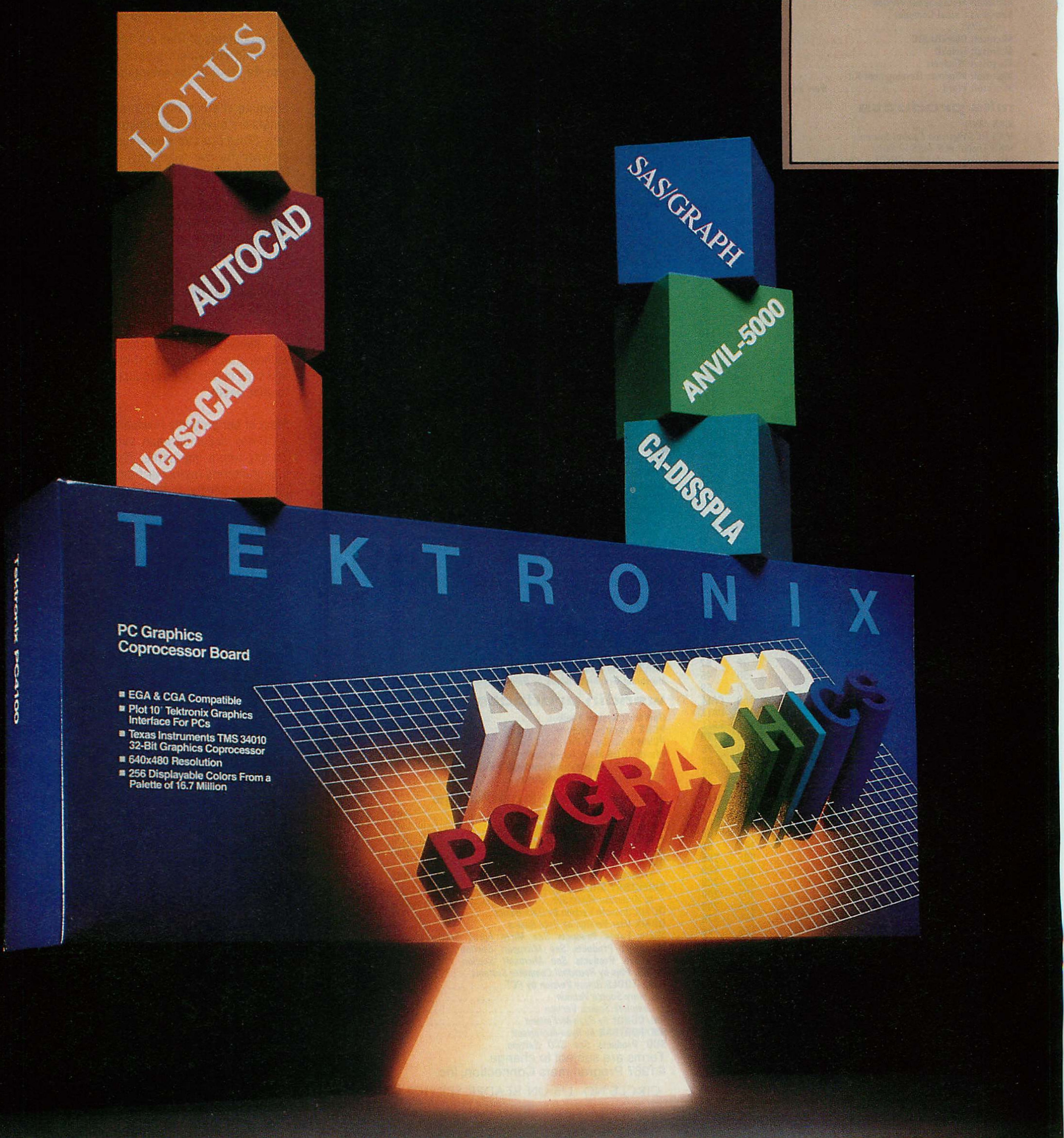

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BOB FELTS

Determining CPU Type

This assembly language procedure works in protected mode and can be incorporated into either a DOS or an OS/2 program.

With the advent of OS/2, a protected-mode operating system, it is useful to have a function to determine CPU type, regardless of CPU operating mode. Previously published procedures of this kind (see "Updating Evaluation the Suite," Ted Forgeron, Paul Pierce, and Steven Armbrust, March 1987, p. 71) work only in real mode because they write to the code segment. The function listed here, **cputype**, can be called by DOS and OS/2 programs in either real or protected mode. It returns a value of 86, 186, 286, or 386 in real mode, and −286 or −386 in protected mode. For brevity, the test to distinguish between the 8086 and 8088 classes of chip is not included (see "Chips in Transition," Bob Smith, April 1986, p. 56).

The first test is a PUSH SP instruction to differentiate between 8086/80186 and 80286/80386 CPUs. If the value on the stack is the same as the SP value after the push, then the CPU is either an 8086 or an 80186. These chips are distinguished by their response to a shift instruction. For a 32-bit shift count, the 8086 will shift 32 bits, clearing the shifted register, whereas the 80186 will not shift at all, leaving the value in the register unchanged.

The next test determines whether the CPU is using 16- or 32-bit operands. This is done by pushing the flags, then testing the change in the SP register to determine whether two or four bytes were pushed. In the latter case, the CPU is an 80386 executing in a 32-bit segment. To load a two-byte immediate value into AX, the MOV instruction must be preceded by a operand-length override prefix. MASM version 4 has no mnemonic for this, so it is generated with a DB instruction at the label **is32bit**.

The distinction between an 80386 that uses 16-bit operands and an 80286 is made by storing the global descriptor table register (GDTR) to a six-byte field in memory. The 80286 stores a −1 to the last byte of this field, whereas a 80386 stores either a 0 or a 1. The space for holding the GDTR value is allocated on the stack (by subtracting from SP), because in protected mode that is the only one of the four segments guaranteed to be writable.

The CPU operating mode (real or protected) is indicated by the low-order bit of the machine status word (MSW). At label **testprot**, the MSW is loaded into a register, the mode bit is shifted into the carry flag, and, if that sets CF, the returned value is negated to indicate that the CPU is in protected mode.

The function follows Microsoft mixed-language naming conventions; because it has no parameters, it needs no declarations to specify the calling sequence. If called from a C program, it must be declared **far**.

Bob Felts is software project manager for Quadram Corporation.

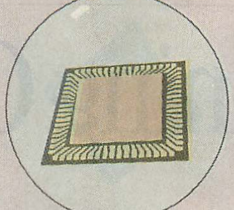
LISTING 1: CPUTYPE.ASM

```
; Function cputype(), for real OR protected mode.  Returns (in AX)
; the value 86, 186, 286 or 386; negative if protected mode.

        .286P                       ;enable protected-mode instr.
_text   segment byte public 'code'  ;use Microsoft C names
        assume  cs:_text
        public  _cputype
_cputype proc   far
        push    bp
        push    sp                  ;86/186 will push SP-2,
        pop     ax                  ;286/386 will push SP
        cmp     ax,sp
        jz      not86               ;if equal, SP was pushed
        mov     ax,186              ;is it 86 or 186?
        mov     cl,32               ;  186 uses count mod 32 = 0;
        shl     ax,cl               ;  86 shifts 32 so ax = 0
        jnz     exit                ;non-zero: no shift, so 186
        mov     ax,86               ;zero: shifted out all bits
        jmp     exit
not86:  pushf                       ;Test 16 or 32 operand size:
        mov     ax,sp               ;  pushed 2 or 4 bytes of flags?
        popf                        ;  restore SP
        inc     ax                  ;  restore AX by 2 bytes
        inc     ax
        cmp     ax,sp               ;  did pushf change SP by 2?
        jnz     is32bit             ;  if not, then 4 bytes of flags

is16bit:   sub     sp,6             ;Is it 286 or 386 in 16-bit mode?
           mov     bp,sp            ;allocate stack space for GDT ptr
           sgdt    qword ptr [bp]   ;(use PWORD PTR for MASM5)
           add     sp,4             ;discard 2 words of GDT pointer
           pop     ax               ;get third word
           inc     ah               ;286 stores -1, 386 0 or 1
           jnz     is386

is286:     mov     ax,286           ;set return value
           jmp     testprot
is32bit:   db      66H              ;16-bit override in 32-bit mode
is386:     mov     ax,386
testprot:  smsw    cx               ;Protected?  Machine status -> CX
           ror     cx,1             ;protection bit -> carry flag
           jnc     exit             ;real mode if no carry
           neg     ax               ;protected:  return neg value
exit:      pop     bp
           ret
_cputype   endp
_text      ends
           end
```



The long-awaited OS/2 will be appreciated by the millions of owners of 80286 machines, but its ultimate strength will depend on how developers implement the program interface.

Enter OS/2

TED MIRECKI

Three long years following the introduction of the IBM PC/AT, the Operating System/2 (OS/2) finally arrives to unlock the full power of the 80286. But the 80286 is no longer the state-of-the-art. Right now, it's the 80386 looking for an operating system to take advantage of *its* features.

Make no mistake: OS/2 is geared to the capabilities of the 80286—it does not make available any 80386 enhancements. This is an operating system based on DOS, with the same file structure, the same file-naming conventions, and most of the same utilities.

For the user, OS/2's major claims to fame are its use of more than 1MB of memory and multitasking. OS/2 can make use of all the physical memory attached to the machine, up to the full address space of the 80286: 16MB of physical memory. It also has a virtual memory manager that can allocate more memory than physical RAM by swapping segments out to disk. This virtual memory space is up to 1GB.

And, users will have to wait for new applications to be written to take advantage of these features. Although OS/2 can run most DOS programs, it can run them only one at a time in 640KB. In fact, the free space available for running programs is less than under DOS, because the same 640KB must contain the real-mode portion of the operating system, which is larger than DOS—about 100KB—compared to 55KB for DOS 3.3.

New OS/2 applications can run in the background with existing DOS applications in the foreground. However, a DOS application is suspended when switched to background. Therefore, OS/2 does not provide the services of a DOS multitasker such as Microsoft Windows or Quarterdeck's DESQview.

One final rub: OS/2 has not yet been released (although beta-test versions are available to developers). Thus, the following articles are not intended as an official review of the system; they are, rather, a review of its design parameters and intended implementation (no bug reports here). We look at OS/2 from five perspectives: user interface, architecture, multitasking capabilities, application program interface, and how one company ported its product from DOS to OS/2.

So when will OS/2 be available? IBM has said it can be *here* in the first quarter of 1988, as Standard Edition version 1.0 with character-based, command-line interface. A subsequent release, 1.1 (availability not yet announced), will incorporate a graphics-based full-screen user interface, the Presentation Manager, which is based on Microsoft Windows.

To put to rest one fear about OS/2, an IBM PS/2 is not required to run it. OS/2 will run on the AT; most compatibles, such as Compaq and Zenith machines; many clones; and, actually, most 80386 machines. Moreover, this new operating system is not an IBM-only product. As it does with MS-DOS, Microsoft will make OS/2 available to OEMs for adaptation to other hardware. In fact, OS/2 will become available to the end-user community only as it is bundled with hardware.

OS/2 system requirements are an 80286 or 80386 machine with a hard disk and 1MB of memory; however, 1MB does not permit a useful real-mode partition for running DOS applications. A full-sized DOS partition of 640KB requires a bare minimum of 1.5MB of RAM, and 2MB to do any useful work. Release 1.0 will run on a monochrome adapter, but once the Presentation Manager is added in release 1.1, OS/2 will require a graphics adapter. At that point, only Enhanced Graphics Adapter (EGA) and Video Graphics Array (VGA) display systems should be considered.

Because the file systems of DOS and OS/2 are compatible, it is quite possible to configure a system to boot up in either OS/2 or DOS. One system must be chosen for installation on the

COMPUTER GRAPHIC • JOE PASQUALE/EDITEL

hard disk; the other one then can be booted from a diskette. It is much more convenient to format the hard disk with OS/2 and boot DOS from a diskette drive because once booted, DOS easily can be configured to find everything it needs on the hard disk, so the boot diskette can be removed. OS/2, however, periodically needs certain files from the boot directory, and no method is available to specify an alternate location for them.

The user interface of OS/2 is uncannily similar to that of DOS. At the command-line level, the casual user may not even notice the difference. Of course, the strength of OS/2 lies not at the command line, but in the environment it provides for applications. Still, to place things in a perspective most users are familiar with, the system-level user interface is compared to the equivalent facilities of DOS.

Just like DOS, OS/2 reads a CONFIG.SYS file at boot-up. The available configuration commands are listed in table 1; many of them will be familiar to DOS users. The new commands fine-tune some of the features specific to OS/2: multitasking, virtual memory management, protection. (For more information, see the other articles in this suite). Notable for its absence from table 1 is the DOS FILES command, which sets the maximum number of file handles that can be open. In OS/2, the file handle tables can grow dynamically as needed, so the number of open files is no longer limited, either system-wide or per process.

A major annoyance during the boot-up process is that errors in the CONFIG.SYS file stop the system with the message "Press a key to continue." This ensures that error messages do not scroll off the screen before being read, but an unattended power-on may hang if there is any problem. A better solution would be to write error messages to a file in the root directory of the boot disk.

Following the configuration step, OS/2 comes up in protected mode and starts up the command processor, called CMD.EXE, as a single task. It then automatically runs the batch file STARTUP.CMD (protected-mode batch files have the .CMD extension to distinguish them from DOS and OS/2 real-mode .BAT files). At this point, the operating system is fully functional and the batch file can perform any command. If the STARTUP file does not start a foreground application, the command processor regains control and displays a command-line prompt. By default, the prompt is the full path name of the current directory enclosed in brackets—for example, [C: \DOS]—but it can be changed, using the same meta-language as in DOS.

TABLE 1: ***OS/2 Configuration Commands***

COMMAND	PARAMETERS[a]	PURPOSE
BREAK	ON/OFF	Sets Ctrl-Break checking for real mode only.
BUFFERS	*number*	Number of disk buffers in memory.
CODEPAGE	*code*	Selects a language-specific code page.
COUNTRY	*code*	Selects country-dependent conventions for displaying time, date, and currency.
DEVICE	*file name*	Installs a device driver.
DEVINFO	*device, file*	Prepares device to accept code page tables.
FCBS	*number*	Number of File Control Blocks that can be open in real mode.
IOPL	YES/NO	Allows or disallows access to I/O hardware if a process requests it.
LIBPATH	*path list*	Specifies locations of Dynamic Link Libraries for runtime loading of procedures.
MAXWAIT	*seconds*	Maximum idle time before a process receives a priority boost.
MEMMAN	[NO]SWAP, [NO]MOVE	Sets options for virtual memory management.
PRIORITY	ABSOLUTE/ DYNAMIC	Sets scheduling options.
PROTECTONLY	YES/NO	Enables running a real-mode session.
PROTSHELL	*file name*	Protected-mode command processor.
RMSIZE	*kilobytes*	Size of real-mode partition.
RUN	*file name*	Start up a process at system initialization.
SHELL	*file name*	Real-mode command processor.
SWAPPATH	*path*	Location of file for swapped-out memory.
TIMESLICE	*milliseconds*	Minimum and maximum time slice.
THREADS	*number*	Maximum concurrent threads system-wide.

[a] *Parameters in uppercase are entered literally; parameters in italic indicate values entered by the user.*

The meaning of most of these commands is similar in DOS and OS/2. The new commands control features such as multitasking and virtual memory management.

The command-line interface, especially in real mode, is essentially unchanged from DOS. Piping and I/O redirection are indicated by the familiar UNIX-like syntax. Another relic from the days of TTY terminals is the command-line editing facility, or lack thereof: the function keys perform the same actions as they do under DOS, and no nondestructive backspace has been added. Users wishing a better interface simply will have to wait for the Presentation Manager.

In protected mode only, the command line supports several new features. Several commands may be typed on the same line by separating them with ampersands (&). In order to allow processing of file names that contain ampersands and other newly reserved characters, OS/2 introduces the escape character, which is the caret (^). The single character following the caret is treated literally. A caret at the end of a command line acts as a continuation character; the system pauses with the prompt **More?**.

Another protected-mode feature is the conditional grouping of commands. A logical AND operation, indicated by &&, performs the command on its right only if the command on its left succeeds. For example, the following command deletes the file LETTER.DOC only if LETTER.BAK exists:

```
DIR LETTER.BAK && DEL LETTER.DOC
```

The logical OR, indicated by | |, performs the command on the right only if the command on the left fails. This is a poor choice of symbol, because it is easily confused with the piping operator indicated by a single vertical bar. Commands also may be grouped with parentheses to override the predefined hierarchy among the various conjunction, delimiter, redirection, and piping operators.

Logical conjunctions can work only if commands return an indication of success or failure, and in protected mode, most OS/2 commands do so. The completion code may be tested

either by the logical operators or by the **errorlevel** statement in batch files. For example, most commands that operate on files (such as DIR and DEL) return an errorlevel of 1 if they find no files matching the command parameter.

The concept is a significant enhancement to the DOS command interface, and could be especially useful in writing more intelligent batch files. Its implementation, however, is less than complete. Very few real-mode commands return error codes, and neither do some very obvious errors, such as attempting to read an empty drive or disk copy a hard disk. Those that do return errors do not use a consistent set of codes; for example, different programs return different codes when terminated with Ctrl-Break. At this point, it is unclear whether this is due to poor design or is merely a stage in the as yet incomplete evolution of this complex system.

Despite these enhancements, the similarities between OS/2 and DOS at the command line far outweigh the differences. What is radically different, however, is that OS/2 can provide several of these DOS-like command lines, and the user can start a program on each. One of these can be the *DOS compatibility environment*, a real-mode static partition where most existing DOS programs can be executed. (For more information on DOS compatibility, see "An Architecture for the Future," Martin Heller, this issue, p. 66.)

Starting separate applications and switching among them is the highest level of multitasking. The means of imposing such control is a hot-key utility that is an integral part of OS/2: the Session Manager. It presents a full-screen menu interface that is a radical departure from anything supplied with DOS. Although the details may change before the final release, and the interface almost certainly will be reworked when the Presentation Manager becomes available, its functions will remain unchanged. Its purpose is to start multiple concurrent *sessions* (also called *screen groups*). The user starts a session by naming a program to be executed; in protected mode, that program may, in turn, start up other processes that may share the same screen.

The Session Manager can be activated at any point, even within a running program, by pressing Ctrl-Esc; this key combination, at least in the preliminary versions of the system, cannot be changed. The current screen is saved in memory, and the current program moves into the background, but unless it is a real-mode program, continues to execute. Of course, background execution may be subsequently suspended if the program needs keyboard input or access to other foreground resources. Depending on how it is written, the program may not need to wait to return to the foreground to write its screen output. (For details and examples of various methods of handling video in a multitasking environment, see "The Flexible Interface," David A. Schmitt, this issue, p. 110.)

The screen produced by the Session Manager is shown in photo 1. The left half displays a list of programs that can be started by name; it contains at least the entry OS/2 Command Prompt, which starts a new copy of CMD.EXE, the protected-mode command processor. The right half of the screen contains a list of programs that have been started. It holds at least the entry CMD.EXE, which is the single task started at boot-up. If the CONFIG.SYS file did not specify protected mode only, another entry, DOS Command Prompt is also listed; it represents the real-mode session.

Command-line similarities between OS/2 and DOS far outweigh the differences, but OS/2 provides several lines for several programs.

Options are selected from the menus by using the cursor keys to move a highlight bar to the item of choice and pressing Enter. On the first switch into real mode, the real-mode command processor (COMMAND.COM) is started. COMMAND.COM runs an AUTOEXEC.BAT file from the root directory of the boot-up drive. Once started, the real-mode session cannot be shut down.

Protected-mode sessions are started either by choosing OS/2 Command Prompt or a program name on the left menu. (The procedure for entering program names into the menu is described later.) In either case, the Session Manager screen disappears and the chosen program is started in the foreground, communicating with the physical screen and keyboard.

Choosing the OS/2 Command Prompt starts up another copy of CMD.EXE, but this invocation does not execute STARTUP.CMD, nor does it inherit the environment from any other session. (The OS/2 environment has the same format and use as in DOS, except that each session has its own separate environment). Once the command prompt appears, the user must issue appropriate commands or run a batch file to set the path and other environmental parameters.

The user may execute any OS/2 command or application program within the command processor session by typing its name at the prompt. The program will inherit whatever environment is currently in effect for this session. CMD.EXE regains control when the program terminates, and the session remains active until the user terminates it by typing the **exit** command. This brings the Session Manager back to the screen. All the protected-mode sessions can be terminated, leaving only the Session Manager running, with the real-mode session, if there is one, suspended in the background.

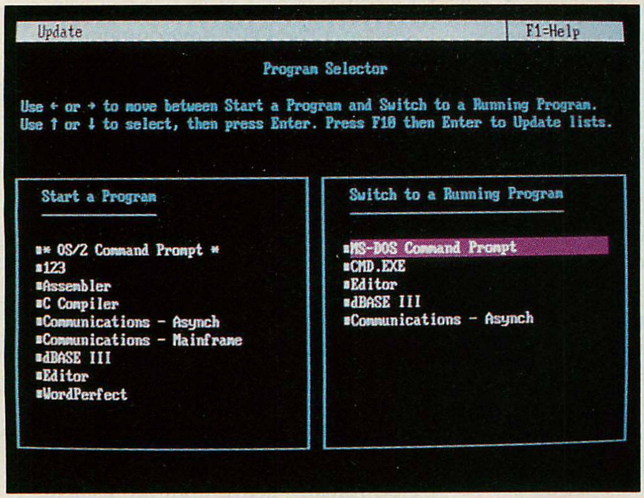
Instead of starting a copy of CMD.EXE to start a program, the user may directly choose a program from the left menu on the screen. The session terminates with the program; if it was running in the foreground, the Session Manager screen reappears.

On the right half of the Session Manager screen, the user can choose a previously started session to be brought into the foreground. That session's screen, updated to reflect any output produced by programs in the background, replaces the Session Manager display. Sessions also can be brought to the foreground without invoking the Session Manager; pressing Alt-Esc switches directly from one session to the next, in the order the sessions were started up.

Two limits are imposed on the number of concurrent sessions. The first is system memory, although if virtual memory management is enabled (by specifying MEMMAN = SWAP,MOVE in CONFIG.SYS), the limit becomes disk space, not physical RAM. The second limit is that OS/2 can support at most 256 *threads of execution* (for an explanation, see "Multiple Tasks," Steven Armbrust and Ted Forgeron, this issue, p. 90). A program can consist of many threads and a session of several programs, so the total number of sessions depends on the design of the applications running together.

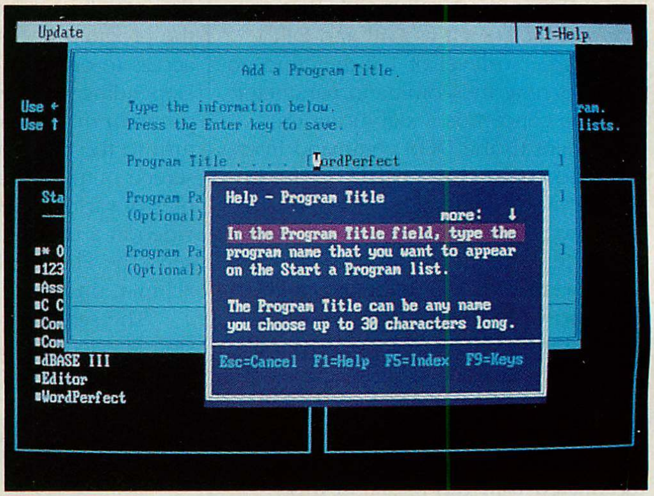
Programs can be added to the left-side menu by invoking the **update** facility of the Session Manager. Pressing

PHOTO 1: ***Session Manager Screen***



The left menu lists programs that can be started; the right menu lists the sessions that have been started. The MS-DOS session is suspended when this screen is displayed, but protected-mode programs can run in the background.

PHOTO 2: ***Program Update Screen***



A menu-driven procedure, a significant departure from the DOS user interface, is used to add, delete, and change program names displayed on the Session Manager's left menu. Context-sensitive help is available in pop-up windows.

F10 opens a drop-down menu from which the user can choose to add to or delete from the program list, change the information for a program, or update the list of running sessions displayed in the right-hand menu. This last choice is used to check if any sessions have terminated since the Session Manager was invoked.

Only protected-mode programs can be entered into the list; real-mode programs must be started from the real-mode command line. Three pieces of information are required for each program: the descriptive title to be used on the Session Manager menus, the full path name of the executable file, and a command line to pass to the program when it is started. Unlike Windows, DESQview, and other environments that control task-switching under DOS, OS/2 does not need .PIF files to specify the characteristics of its programs. It deals automatically with any program behavior that is allowed in protected mode.

The Session Manager's update facility exhibits some of the flashiest behavior ever seen in an operating system utility. Its functions are performed amid a blizzard of colorful windows, and context-sensitive help can be popped up in still more windows (see photo 2). The only drawback is that the color cannot be turned off, so the screen becomes difficult to read on a single-color graphics screen—a Compaq, for example.

Programs that run only in the background can be started by two other methods besides the Session Manager. One is by a **run** command in CONFIG.SYS, the other by a **detach** command at the protected-mode prompt (or from a .CMD batch file). In either case, the program must be able to run without keyboard input, and must write its output to somewhere other than the screen. Standard OS/2 commands can be run this way if I/O is redirected. If the process requests keyboard input, it will wait indefinitely; screen output appears to succeed, but is routed to a bit bucket. A background-only process must have some way of terminating itself, because it cannot be terminated by the user.

Most of the internal and external command of DOS have been carried over to OS/2. Six of them are restricted to real mode: **append**, **assign**, **break**, **graftabl**, **join**, and **subst**. In addition to the **detach** command described above, the following four new commands are added:

Ansi is an external command that enables or disables support for ANSI escape sequences for console control in protected mode only. In real mode, ANSI support is installed as in DOS, by loading ANSI.SYS at boot time; once installed it cannot be disabled.

Dpath, an internal command, specifies a list of directories in which to search for data files; it performs in protected mode the same function that **append** (introduced in DOS version 3.3) performs in real mode and that **path** performs in both modes for executable files. **Dpath** is entered into the environment, therefore, it applies only to the session in which it is issued.

Helpmsg, available in both modes, displays an explanation of OS/2 error messages. When an error occurs, the system displays an error number and a short message, for example:

DOS0193 Unacceptable executable format

Issuing the command **helpmsg DOS0193** produces several lines explaining that either the file is damaged or it is a real-mode file, and suggesting that the user attempt running it in real mode. It is highly inconvenient to have to enter the error code; an intelligent message system would save the last code issued and use it if the command were entered without a parameter. As it is, typing the **helpmsg** command alone produces yet another cryptic error message. Incidentally, the error codes for these messages have no relation to the error level, if any, returned by the failing command.

Patch is a utility for hexadecimal editing of files. It is a very poor version of the E (enter) command of DOS DEBUG. It reads in a specified file, displays its length in hexadecimal format, and asks the user to enter a hex offset. It then displays 16 bytes beginning at that offset in DEBUG dump format, allowing the user to cursor over the line and overtype any of the displayed hexadecimal characters. Cursor control is somewhat counter-intuitive, because nondestructive movement is performed with the space bar and Backspace key.

This utility is provided because no equivalent of DEBUG has been included, not even for real mode. A DOS version of DEBUG will not run in the

Continued on p. 63

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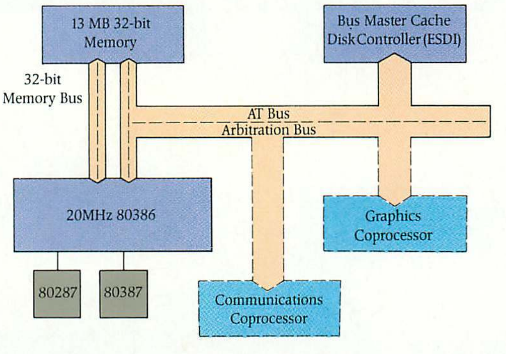

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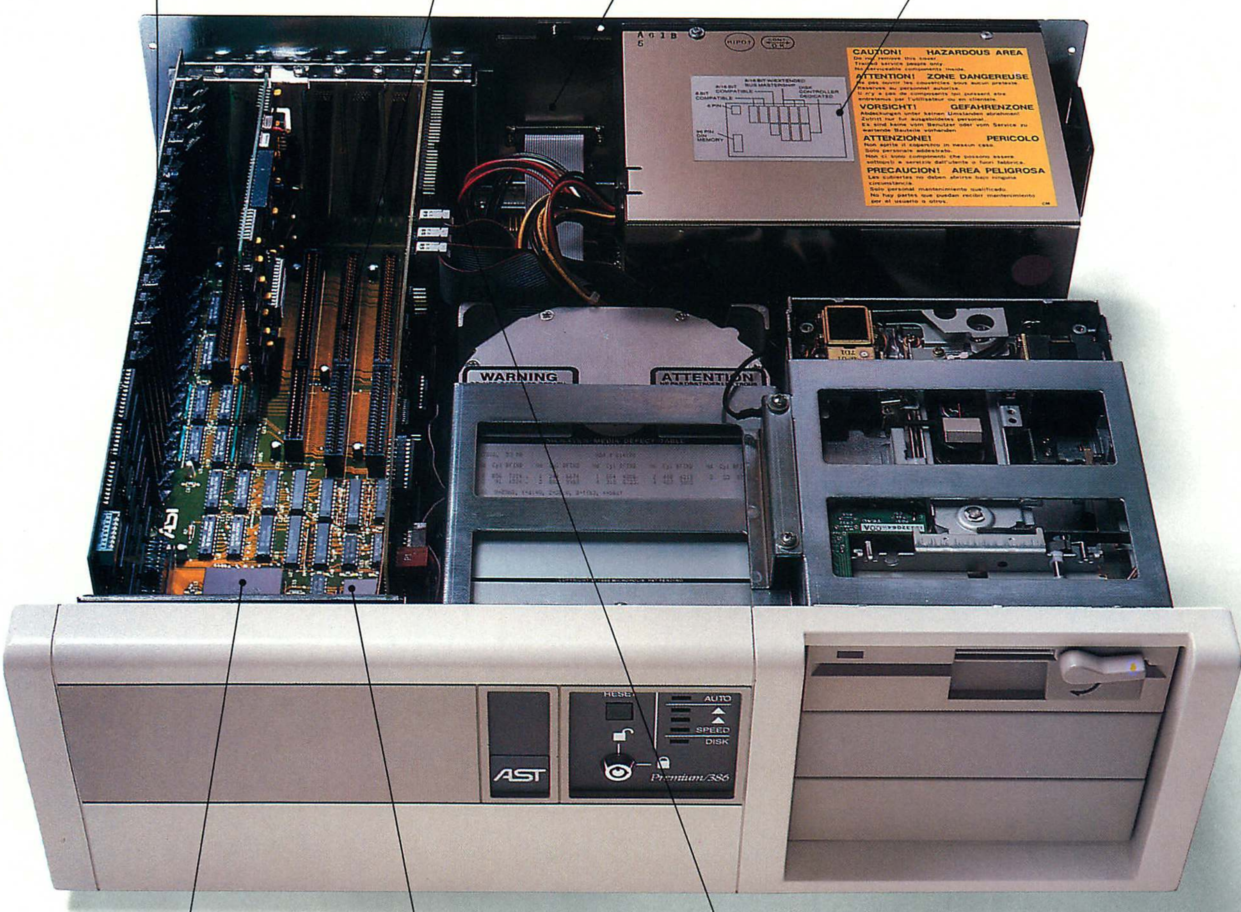

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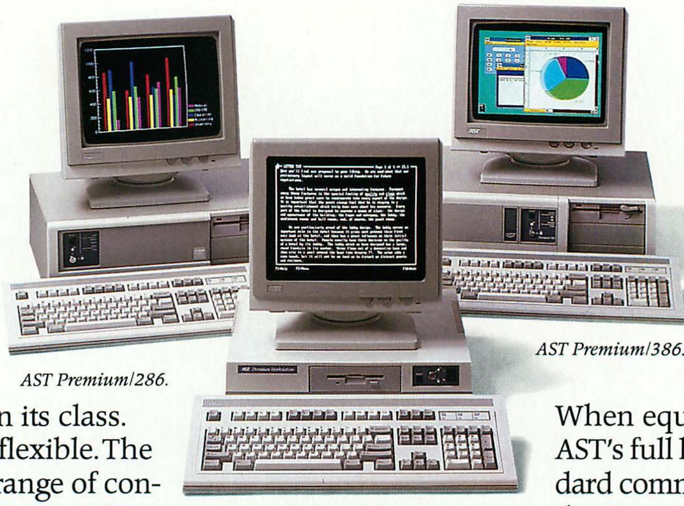

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TABLE 2: ***OS/2 Performance***

MODE	SESSION	MULTITASKED WITH	TIME[a]	PERCENTAGE SLOWER
DOS	FG	N/A	9.6	(Base)
Real	FG	Nothing	10.8	13
Real	FG	Disk format in BG	11.5	20
Real	FG	High-compute in BG	12.8	33
Protected	FG	Nothing	10.9	14
Protected	FG	Disk format in BG	11.9	24
Protected	BG	Disk format in FG	15.0	56
Protected	FG	High-compute in BG	17.9	86
Protected	BG	High-compute in FG	18.6	94
Protected	BG	BRIEF Editor in FG	455.0	4640

FG = Foreground
BG = Background
[a] *Time in seconds taken by OS/2 family-mode MASM, assembling DOS 3.3 version of VDISK.ASM.*

The assembly of a large file was timed under various conditions. Most results are reasonable, except that foreground editing greatly inhibits background assembly.

compatibility box because DEBUG is version-sensitive, but SYMDEB or another debugger will. Microsoft is supplying with the preliminary OS/2 Software Development Toolkit a protected-mode version of the CodeView source-level debugger, and a more low-level tool for debugging system software in protected mode is promised with the production release.

Three new commands were created for use in batch files. **Setlocal** saves the current drive, directory, and all the environment variables so that the batch file can define local values that are in effect only until an **endlocal** command or the end of the file. These commands do not nest; the first **endlocal** or end of file restores the values in effect before the first **setlocal**.

The third new batch command, **extproc**, invokes a temporary command processor to execute a batch file. It must be the first command in the file; all the subsequent commands are then executed by the named program. This is useful for implementing an enhanced batch processor without requiring the user to invoke it by name. For example, assume the new batch processor's name is **superbat**. Under DOS, if the user wanted this processor to execute the list of commands contained in the command file **runlist**, he would need to type **superbat runlist**. Under OS/2, he could insert the line **extproc superbat** at the top of the command file, and invoke the special command processor simply by typing **runlist** at the prompt. The point is, the user need not know which command files are for the standard command processor and which for a special one, because the files themselves specify this.

The other utilities operate essentially as in DOS 3.3. The major difference is that CHKDSK includes the report on memory usage only in real mode; this information cannot be obtained in protected mode. Granted, memory allocation in a system with multiple tasks and a virtual memory manager is potentially in a state of constant flux, but it would be useful (especially to developers who are fine-tuning an application under controlled conditions) to get a snapshot at a particular point in time. This information must be kept somewhere in the system, so why not make it available and let the user decide its usefulness?

FIRST IMPRESSIONS DECEIVING?

The question that is foremost in the minds of most prospective OS/2 users must be, "How does this new system perform?" The prerelease version is still evolving, so it is too early to give a definitive answer, but we have some indication of what users can expect.

In the first place, there is no doubt that for most operations, OS/2 will be slower than DOS, simply because many CPU operations take more clock cycles in protected than in real mode. Second, a task running along with other tasks will take longer to complete, in terms of realtime, than the same task running alone.

However, the advantages of OS/2 are not measured fairly simply by its raw speed in a single task, but by the overall productivity gains that it makes possible. For example, two copies of the same task running together will not take twice as long as one copy running alone. Therefore, the user gains time over performing the task twice in sequence in a single-threaded operating system such as DOS.

To obtain some indication of an order-of-magnitude comparison of performance between OS/2 and DOS, the assembly of a large source file was timed under a variety of conditions. Microsoft MASM 4.5 (supplied with the OS/2 SDK) was used. It is a family-mode program that can run under DOS and either mode of OS/2. The source file was VDISK.ASM, supplied with IBM PC-DOS 3.3. It needs an include file—which IBM does not provide; to allow the assembly to proceed, the include statement in the source was commented out. As a result, the assembly generated one error because of an undefined symbol.

The assembly was run in OS/2 under nine different conditions; table 2 lists the results, with a comparison to the performance under DOS. The high-compute program is a C language version of the Savage benchmark used in "BASIC Face-Off" (Justin Crom, September 1987, p. 136).

For the most part, the results follow expectations: the assembly takes longer when running along with another task than when running alone, and longer yet if assembling in the background. The one surprise is the performance in the background when the foreground is running an editor: the assembly slows to an unacceptable crawl, taking well over seven minutes. This is not a problem with the BRIEF editor, because the same results were obtained when the foreground process was WordPerfect, Microsoft Word, or Lotus 1-2-3. Obviously, some work is still needed on this front.

Other than that, the performance is quite respectable. Increasing the time by 50 percent or less is barely perceptible, and even a 100 percent increase is acceptable if the user can do something useful in the meantime.

At first glance, OS/2 will not be very impressive to the user. But this is no reflection on its design, because a good operating system should blend into the background while allowing application programs to shine. OS/2 conforms to that principle—its strength lies mainly in its interface to the application, not to the user. Whether OS/2 is widely accepted by the end-user community ultimately depends on how well it is accepted by developers and what they do with the program interface. Just like hardware, an operating system is sold not on its own individual merits but on the strength of the applications software it can run.

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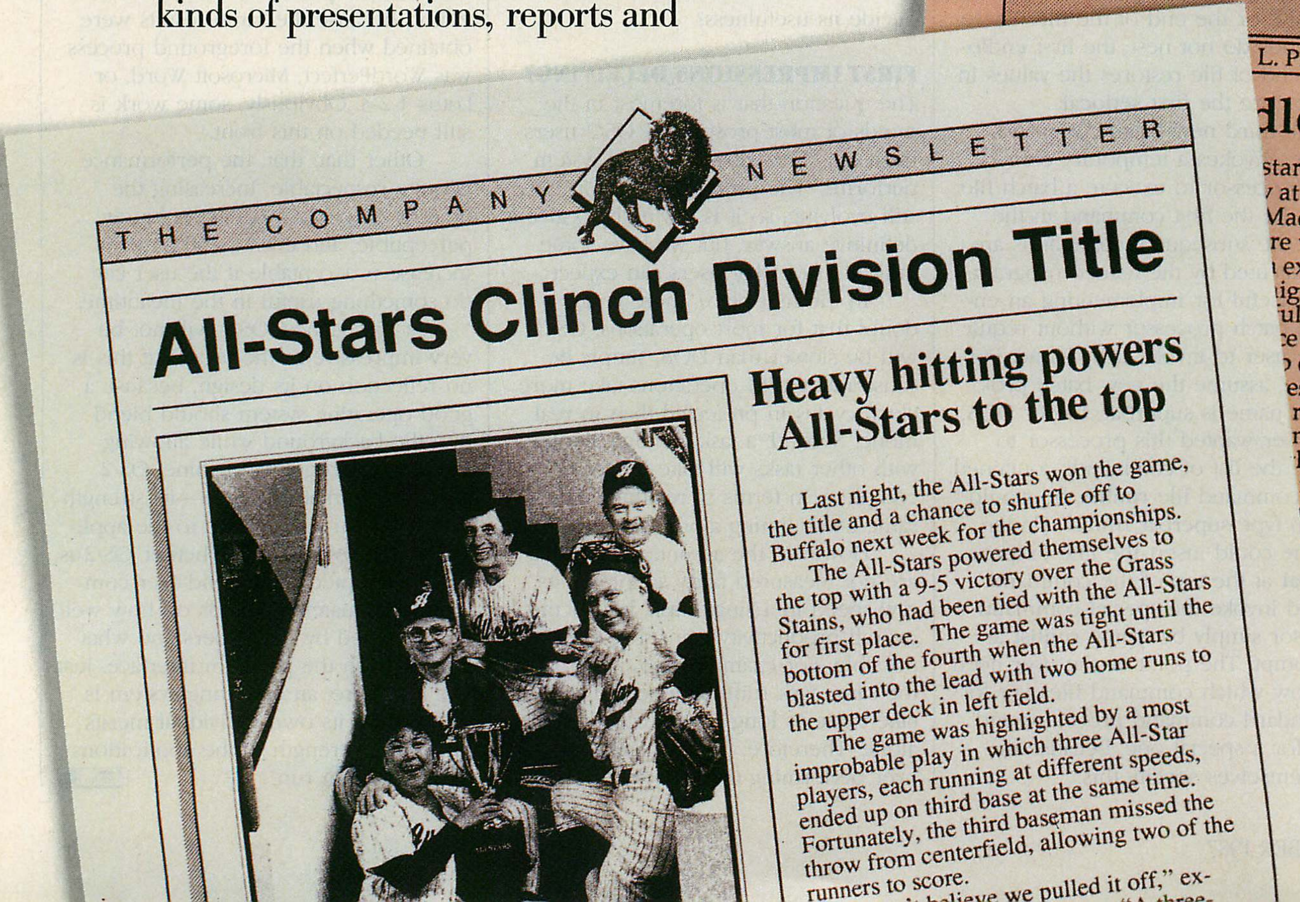

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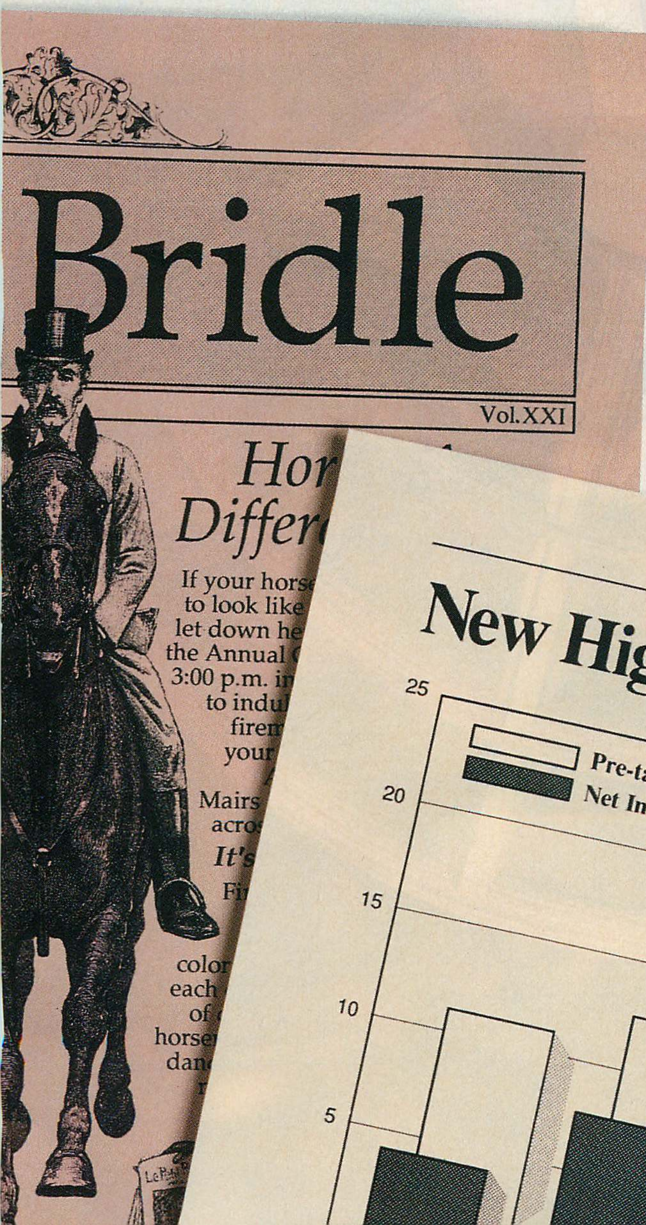

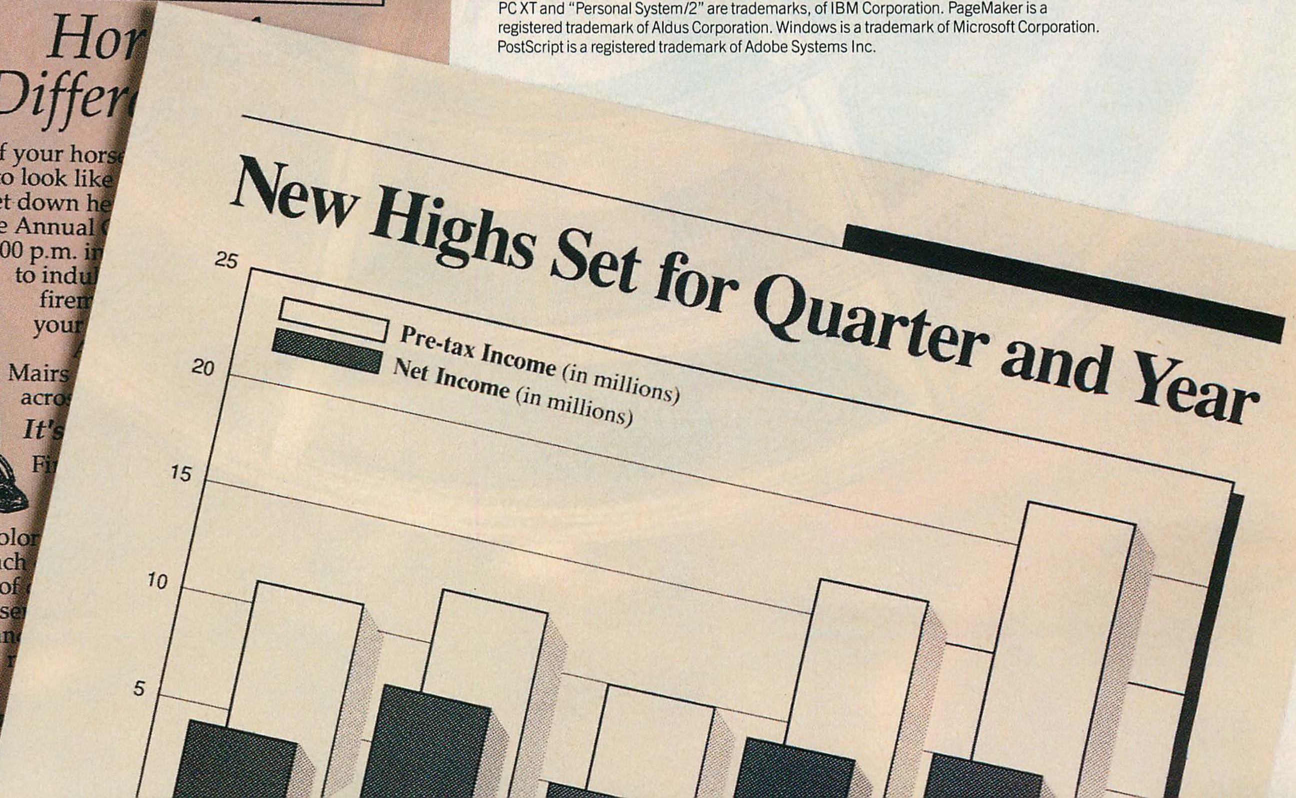

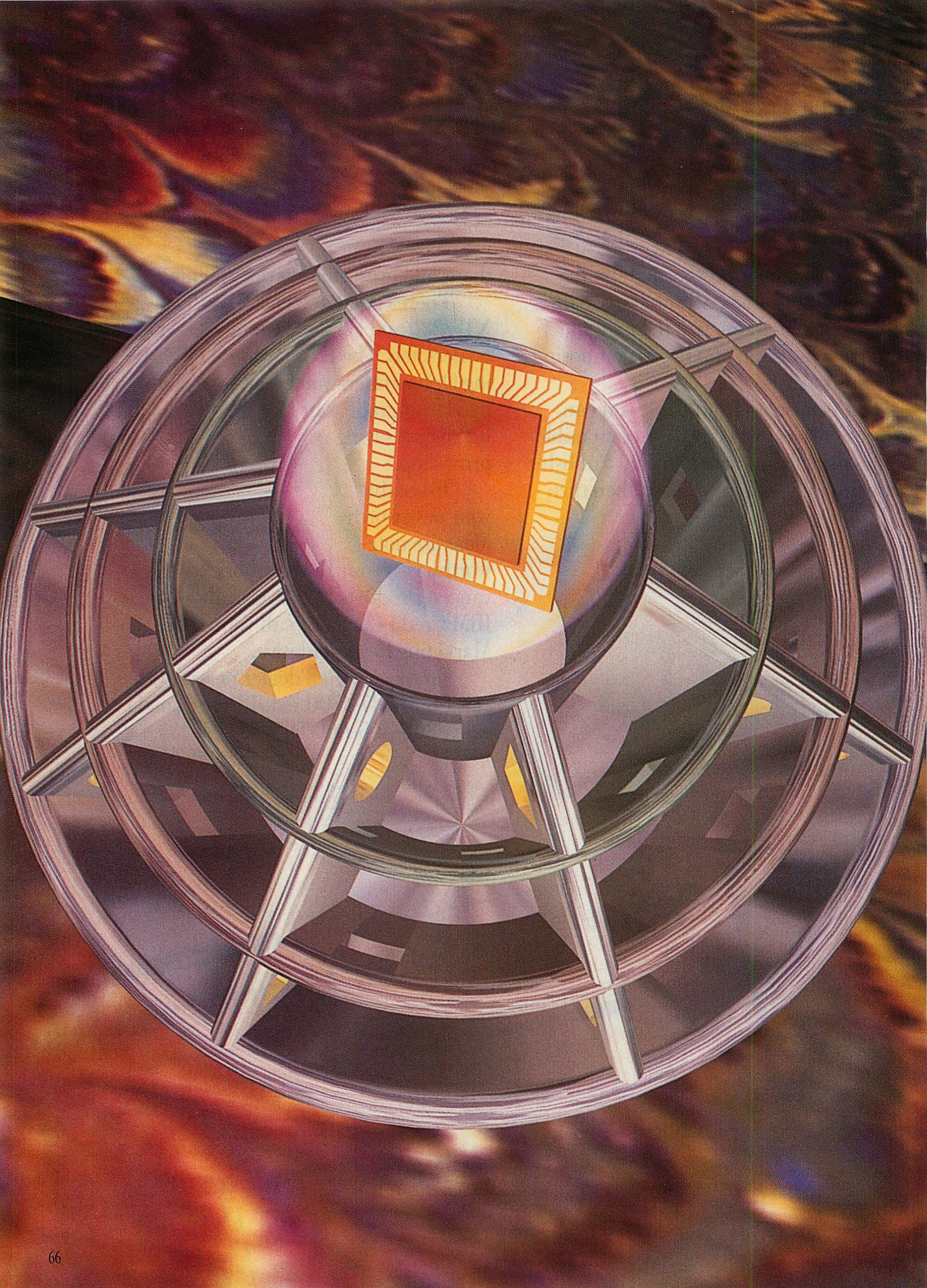

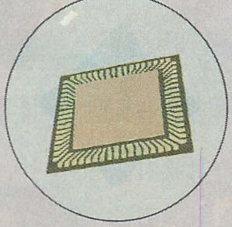

OS/2 favors the convenience of a single user not the maximum utilization of hardware.

An Architecture for the Future

MARTIN HELLER

The Operating System/2 (OS/2) is the latest, most ambitious project ever undertaken by Microsoft, towering well over MS-DOS, Windows, Word, and other major languages. Its features are reminiscent of operating systems such as UNIX, MULTICS, VMS, and RSX-11M; at the same time, it remains largely compatible with MS-DOS.

Like the above-mentioned operating systems for much larger computers, OS/2 unleashes all the power inherent in the hardware while keeping a tight rein on the applications tapping that power. But unlike most of these systems, OS/2 has, as a primary design consideration, the convenience of the single user, not the maximum utilization of the hardware. Faced with a choice between responding to the user or getting the maximum MIPS out of the CPU, OS/2 favors the user.

In that dim prehistoric era (until a few years ago) when computer iron was expensive and user time was cheap, operating systems primarily were driven by the need to get the maximum throughput from expensive hardware. A big OS/MVS system operator would try to balance the running of I/O-bound and CPU-bound jobs to maximize the number of CPU-minutes and I/O operations billed per day.

Today, user and programmer time costs more than computer time. OS/2 matches this new perspective with an innovative approach to system scheduling that gives top priority to whatever task the user brings into the foreground, regardless of its effect on overall system throughput. In OS/2 minimizing the idle loop was not a primary design consideration.

Unlike DOS, OS/2 is built in layers, as shown in figure 1. Sandwiched between applications at the top and hardware at the bottom are three system layers: the subsystems, the kernel, and the device drivers. While the three system levels interact, their purposes are distinct: subsystems supply the applications program interfaces (APIs), the kernel provides basic system services, and device drivers manage the intricacies of hardware. This design reflects the modern software-tools approach; each piece of the system performs its specialized task and passes information to another piece. The modular design makes subsystems and device drivers easy to replace. Plug in a new hardware device, copy its driver file, make a change to the CONFIG.SYS file, reboot the system, and a new version is up and running! In contrast, minicomputer systems require a time-consuming system generation to install a new device or update any part of the operating system.

The kernel constitutes the "nerve center" of OS/2: memory management, task scheduling, interprocess communication, file I/O, timer services, environment management, and basic text message facilities. For the programmer, kernel services are an arms length away; the API implemented in dynamic-link libraries (DLLs) is at his fingertips. The API is implemented quite differently from DOS. Service functions have names instead of numbers and are entered with calls rather than interrupt instructions. Parameters are passed on the stack rather than in registers. The calling protocol is the same as produced by many compilers, so OS/2 functions can be called from high-level languages such as C, Pascal, or FORTRAN (see "The Flexible Interface," David A. Schmitt, this issue, p. 110).

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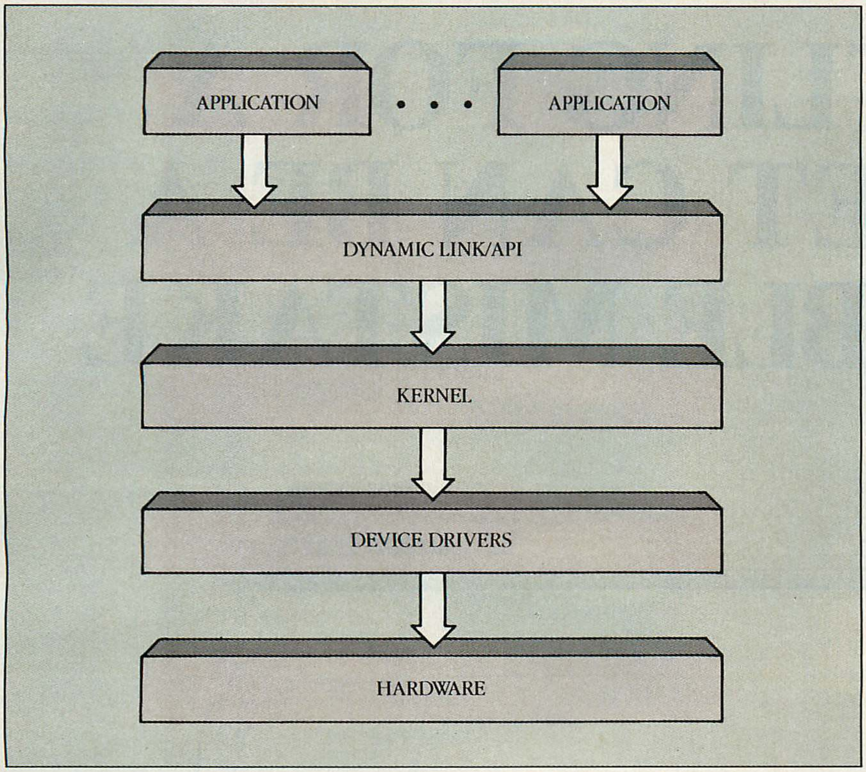
FIGURE 1: ***OS/2 Overall System Structure***



The structure is more layered and modular than that of DOS. Not only device drivers but entire subsystems such as the video and the file system can be expanded, enhanced, or replaced outright without changing the kernel.

A more significant difference between the OS/2 API and DOS is that API routines are not an integral part of the kernel but are separated into DLLs. These are similar to link-time libraries in that they contain executable code of modules called from other modules. This code, however, is not bound into the main module by the linker but brought into memory either at load time or at call time. Implementing the API by dynamic linking is quite advantageous to the operating-system designers, chiefly because the system lends itself to modification and extension. API services can be replaced simply by providing a new DLL containing modules that perform these services.

Dynamic linking presents opportunities for applications developers as well as for Microsoft. General-purpose utility libraries for database, graphics, or communications management can be distributed as DLLs instead of link-time libraries. In addition to easy upgrades and extensions, this approach's advantages are twofold. First, the distributed .EXE files are smaller. Second, several applications running concurrently can share one copy of the dynamically linked code in memory, provided that the routines are reentrant.

While the kernel encases the core of the operating system and the DLLs hold interfaces and extensions, the device drivers are the hardware-specific parts. These can be as simple as a system clock driver or as complicated as a network driver, and run the gamut with drivers for the keyboard, mouse, screen, and disk drives. As in DOS, device drivers permit hardware manufacturers to tailor OS/2 to their system in a way transparent to applications. Drivers can provide low-level access to the system for special applications, as they have system privileges.

OS/2's modular and expandable design allows add-on enhancements that can alter user and application system interfaces. This feature allows additions to OS/2 of a graphic user interface (the Presentation Manager, based on Microsoft Windows, announced for version 1.1) and significant enhancements to the API (database and communications services of IBM's future Extended Edition).

THE HARDWARE ENVIRONMENT

OS/2 runs on the 80286 and 80386 CPUs but not on the 8088, 8086, or 80186. Therefore OS/2 runs neither on the IBM PC and PC/XT nor on the IBM Personal System/2 (PS/2) Model 30. In marked contrast to UNIX, which is designed to run on a variety of systems with different architectures, OS/2 is optimized for its CPU and is unlikely to be ported to a non-Intel architecture. The operating-system architecture and capabilities are intrinsically linked to the 80286's architecture, with some room for enhancements to support the 80386. Therefore, understanding OS/2 requires some knowledge of the underlying hardware architecture.

Both the 80286 and the 80386 CPUs can operate in either the *real* or the *protected* mode. In real mode, the CPUs simply behave as fast 8086 chips and are limited to a 1MB memory address. Memory is addressed by the physical address, and any program, be it an application or the most crucial part of the operating system, can access any part of memory space.

Protected mode makes a larger address space available. The 80286 can address 16MB of real memory (RAM connected to the machine) and 1GB of virtual memory (address space implemented by swapping segments to and from disk).The 80386 can address 4GB of real memory and 64TB—that's 64 *trillion* bytes—of virtual memory. Of course, there are other constraints: few personal computers today come equipped with more than 1 or 2MB of RAM and 30 or 40MB of hard disk space. Protected mode's salient quality is that it protects memory from being overwritten by an errant program. This is an invaluable tool in debugging and is the only way to preserve system integrity in a multitasking environment.

The first method of protection is to allocate each task a memory space completely disjoint from that of any other task. The hardware, not the operating system, checks that all memory references are within a task's allotted space. Any attempt to access, even to read from, a location outside this space is suppressed and causes a *protection exception* interrupt. This returns control to the operating system, which terminates the task. The result is clean isolation of tasks from one another at no cost in software overhead.

A second method of protection is to isolate the various functions of a task into four privilege levels, numbered zero through three. The privilege levels do not imply an execution priority but impose a set of validation rules for control transfers and memory accesses within a task. Level zero has highest privilege and can execute any hardware instruction; it is meant for "trusted

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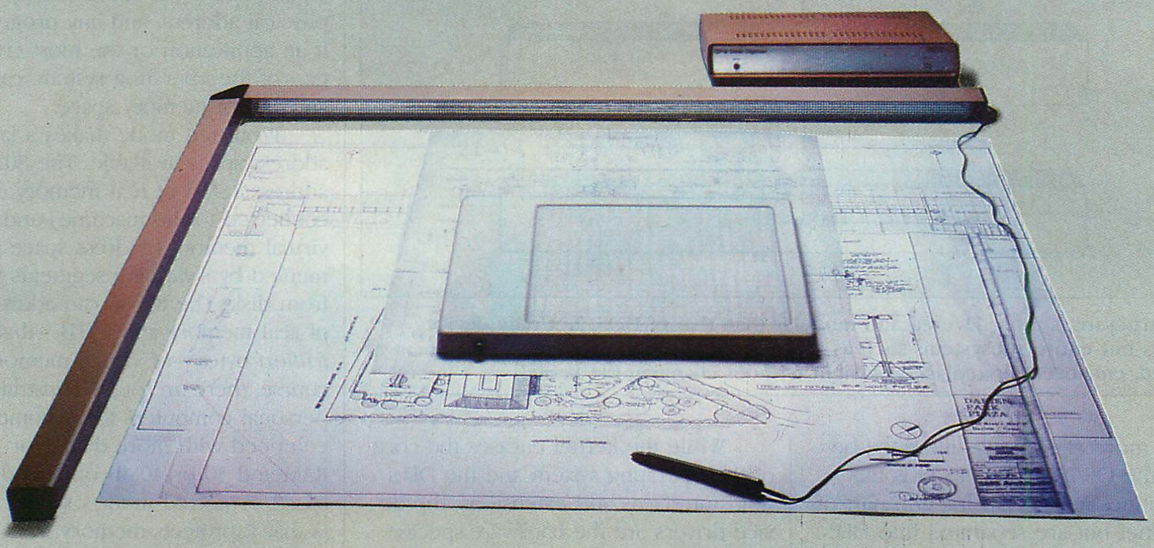

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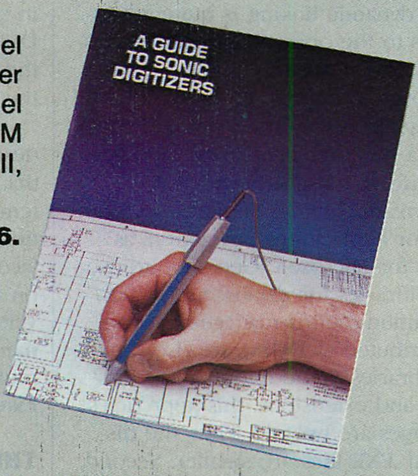

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code" such as the operating system. Level 3 has lowest privilege. For information on the hardware-level protection implemented on the 80286, see the sidebar, "How Protected Mode Protects," Ted Mirecki, p. 80.

OS/2 uses level 0 for the kernel and device drivers, level 2 for special-purpose I/O routines, and level 3 for applications. Level 1 is currently unused. Applications at level 3 cannot access I/O ports nor can they set or clear interrupts. Some API calls are handled entirely within level 3; some are routed via a call gate (explained in the above-mentioned sidebar) to the kernel.

Code at level 2 can disable and enable interrupts with the CLI/STI instructions and access ports with IN/OUT instructions. This allows an application, for instance, to communicate with a data acquisition board not provided with a device driver. A program segment can be marked as intended for level 2 by declaring it an IOPL segment at link time. But at run time, IOPL is granted only if the system is booted with the statement IOPL = YES in the CONFIG.SYS file. Thus, by configuring the system appropriately, the user can choose whether to allow applications that need direct access to the hardware.

At level 0, the system is wide open; here, a process can allocate memory, build descriptor tables, adjust task scheduling, program the direct memory access (DMA)—in short, do what the operating system does. Device drivers' operation is split between level 0 and application privilege; this point is discussed later in the article.

OS/2 supports both real and protected modes. Real mode simulates the DOS environment for compatibility with existing applications; it is discussed in the section on DOS compatibility. Protected-mode programs can benefit fully from all OS/2 services.

Mode switching on the 80286 is an interesting problem. The chip was designed to switch easily from real to protected mode (by merely turning-on a bit in a status register), but not from protected to real mode. Gordon Letwin, chief designer of OS/2, compares the mechanism that Microsoft uses to overcome this difficulty to "turning off the car to change gears," because a full system reset must be done on the fly. Doing this while running multiple tasks without losing any of them is not an easy task: it takes up to a millisecond, during which interrupts cannot be serviced. On the 80386, this is unnecessary because mode switching in either direction is done merely by setting bits. This is the one instance when OS/2 uses the 80386's special capabilities.

THE MULTITASKING EDGE

The greatest productivity gain in OS/2, compared with DOS, is its ability to run several programs concurrently. Since the user simply can switch from task to task without exiting one program and loading another, he can tailor the computer to his needs instead of trying to adjust his work schedule to the computer. One other major advantage of multitasking is that long tasks can be run in the background while other interactive work is performed in the foreground. Actually it is an improvement over having two computers, because tasks can be synchronized and can exchange data with one another.

In scheduling multiple tasks, OS/2 uses a *prioritized preemptive* scheduling algorithm. *Prioritized* means that each time the scheduler executes, it starts up the highest-priority task ready to run (one not waiting for completion of some external event such as I/O or resource availability). If there are several such tasks with equal priority, they take turns in round-robin fashion (the next one started is the one suspended the longest).

One other advantage of multitasking is that long tasks can be run in the background while other interactive work is performed.

Preemptive scheduling means that a task can be interrupted, and control given to the scheduler, by events external to the task. The alternative method, called *event-driven* scheduling, does not perform a switch until the currently executing task becomes blocked, that is, must wait for some event to occur before it can continue. In OS/2, a task obviously must be suspended when it blocks, but it can also be preempted by any of three external events:

- The task calls an API service that releases some resources. If any higher-priority tasks consequently become unblocked, one of them is started.
- A hardware interrupt indicating I/O completion occurs. If some higher-priority task was waiting for this I/O, it is now started.
- A timer interrupt occurs if neither of the two events above occur in some specified time interval (which is called the *time slice*).

Note that each event merely causes the scheduling algorithm to be executed but does not cause a task switch. If the preempted task still is the highest-priority unblocked task, it resumes execution. In effect, the highest-priority task continues to run (with time-outs for scheduling interrupts), until it becomes blocked or a higher-priority task becomes unblocked.

OS/2 controls multitasking on three levels. On the top-most level is the *session*, also called a *screen group*, typically started by the user by means of the Session Manager (see "Enter, OS/2," Ted Mirecki, this issue, p. 52). In most cases, each stand-alone user-level task is a separate session. For example, if a user wants to perform a database sort in the background while switching between a word processor and a spreadsheet in the foreground, he needs to start three sessions. Each session is allocated one logical screen buffer, which is displayed on the physical screen when that session is switched to the foreground.

A screen group is composed of one or more *processes*. A process is what a user thinks of a program and is associated with an executable file on disk. It can be started by the user from the operating-system prompt or by another process. In most cases, all of the processes simultaneously displaying windows on the screen must belong to one screen group.

At the lowest level, the tasks that OS/2 actually schedules are called *threads*. Each process has one or more threads or paths of execution running concurrently. The main thread of a process begins at the entry point of the program and is started by the loader; subsequent threads may be started by system calls executed within this main thread. Creating a thread is similar to calling a subroutine, but the return to the calling thread occurs as soon as the child thread is created, not when it finishes executing. OS/2 imposes a limit of 255 threads for the entire system.

This multilevel structure addresses two different aspects of multitasking. The user can control the concurrent execution of applications as sessions, while the developer has the flexibility to design applications whose functions are distributed over a set of concurrent cooperating processes and threads.

Multitasking can reach its full potential only when concurrent tasks are

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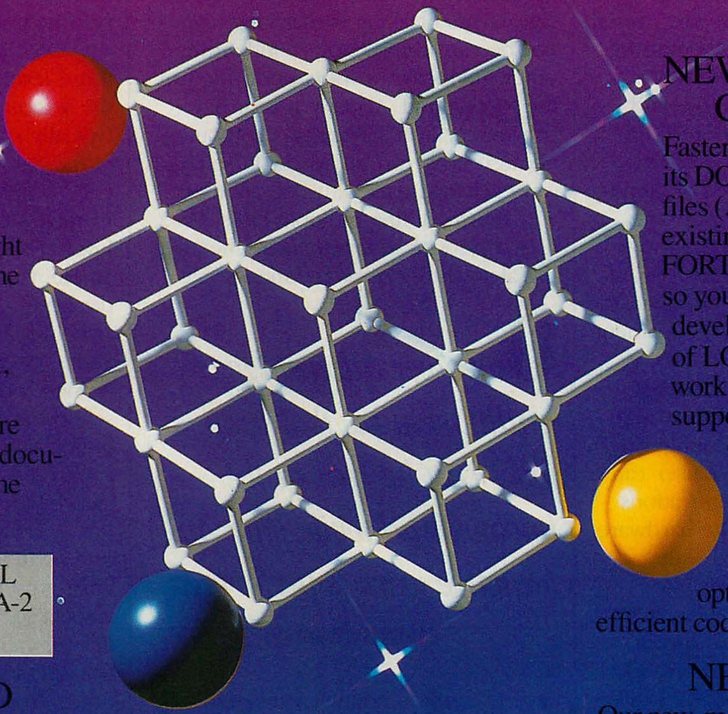

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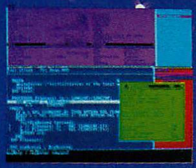

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able to communicate with one another. The threads of one process, being part of the same program, automatically share the same data space and files (subject to the scoping rules of the language in which they are written); each process, however, is allocated a distinct set of memory and file resources. The protection mechanism of the 80286 microprocessor isolates processes from one another, unless they are designed in advance to communicate with one another. OS/2 offers abundant facilities for interprocess communications, for the dual purpose of process synchronization and data transfer.

Synchronization can be controlled by *semaphores*, named switches that can be set and tested to determine such yes/no conditions as "is this process still running" or "is the printer busy." A semaphore can be created, set, tested, and cleared by different processes, as long as all of them have been programmed to refer to the semaphore by the same identifier.

Three methods are available for data transfer among processes. The simplest and fastest of these uses a named block of *shared memory* that is mapped into the protected address space of each cooperating process. File-like I/O can be performed via in-memory structures called *pipes* and *queues*; these simulate, respectively, sequential and random-access files.

Multitasking and interprocess communication in OS/2 is a vast subject; it is discussed in detail in the companion article, "Multiple Tasks," by Steven Armbrust and Ted Forgeron, p. 90.

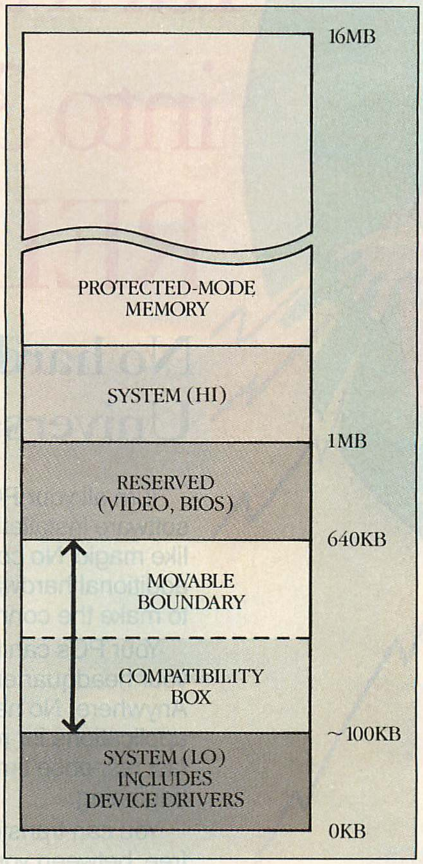
MEMORY MANAGEMENT

To many users and developers, OS/2's greatest attraction is possibly that it finally breaks the 640KB barrier. OS/2's address space corresponds to that of the 80286: 16MB of physical RAM mapped to 1GB of virtual address space. The larger address space of the 80386 is not supported by OS/2.

The general layout of OS/2 memory is shown in figure 2. The resident part of the operating system is two part: *System (Lo)* and *System (Hi)*. The real-mode partition, shown in figure 2 extending to 640KB, can be reduced or eliminated entirely, depending on entries in the CONFIG.SYS file. However, with System (Lo) taking up 100KB, most users with a real-mode partition will want it as large as possible.

Note that this requires 1.5MB minimum RAM and twice that for good multitasking performance. OS/2 is not designed for minimum hardware; it is

FIGURE 2: ***Memory Use***



At last, full 80286 memory space is available. OS/2 can run most DOS programs in the compatibility box but offers less free memory than DOS as its real mode is larger.

no accident that the OS/2 development team at Microsoft works with 80386-based machines with lots of RAM and with big, fast hard disks.

In protected mode, OS/2 implements a virtual memory-management system based on the descriptor-table address mapping that underlies the architecture of the 80286 (see the sidebar "How Protected Mode Protects," p. 80). If physical memory is not sufficient to satisfy an allocation request, the contents of some memory segment are swapped out to disk, and the *present* bit in that descriptor is turned off. The allocation is made from the memory that was freed as a result. When the swapped-out segment is subsequently referenced, the addressing mechanism generates a *not-present* interrupt. OS/2 blocks the task that uses this segment and starts up a system thread to read-in the missing segment (this may, in turn, cause another segment to be swapped out). After the segment has been read-in, its descriptor is updated so that it accurately reflects the new location, and the waiting task is unblocked and becomes eligible for rescheduling.

Swapping can be disabled if there is sufficient memory to load everything that needs to run at once. Swapping *should* be disabled in a realtime environment, because the delays caused by not-present faults could be unacceptable in a time-critical application.

Another possibility is that enough memory is available to satisfy a memory allocation request but that it is in several pieces scattered around the machine. In this scenario, OS/2 will move segments around until it has made a "hole" that is big enough to satisfy the request. Because the absolute location of segments is carried only in the descriptor tables (which are updated by the kernel when the movement occurs), the processes that use those segments do not require notification when segments are relocated by either swapping or moving.

In some cases, memory can be released simply by discarding a segment (marking it *not-present* in its descriptor) without writing it out to disk. Pure code is not swapped; it is discarded and later reread from the .EXE file if necessary. An application also may mark some of its data segments discardable as one way to give the operating system some flexibility in memory management. Discardable segments are useful for data that could easily be regenerated or reloaded, for instance, pieces of screen bitmap under a pop-up window or database cache buffers. For more information on managing discardable segments, see the article, "The Flexible Interface," p. 110.

Another way to influence the system's memory-management algorithm is to link an application with some segments marked "preload" and others "load on demand." The latter delays memory allocation until it is absolutely necessary. In the meantime, more memory is available for other processes. Other suggestions for affecting memory efficiency at the source-code level are given in the sidebar, "Coding for Virtual Memory," p. 75.

In order to ensure reasonable performance (see the section on timing specifications), OS/2 fixes some segments in real memory and does not allow them to be swapped out. These include the kernel code and data and the interrupt-time code for device drivers (described later). Also, the system reserves six segments of 64KB each that are allocated as a last resort when critical segments swapped out must be brought back in. All other memory is

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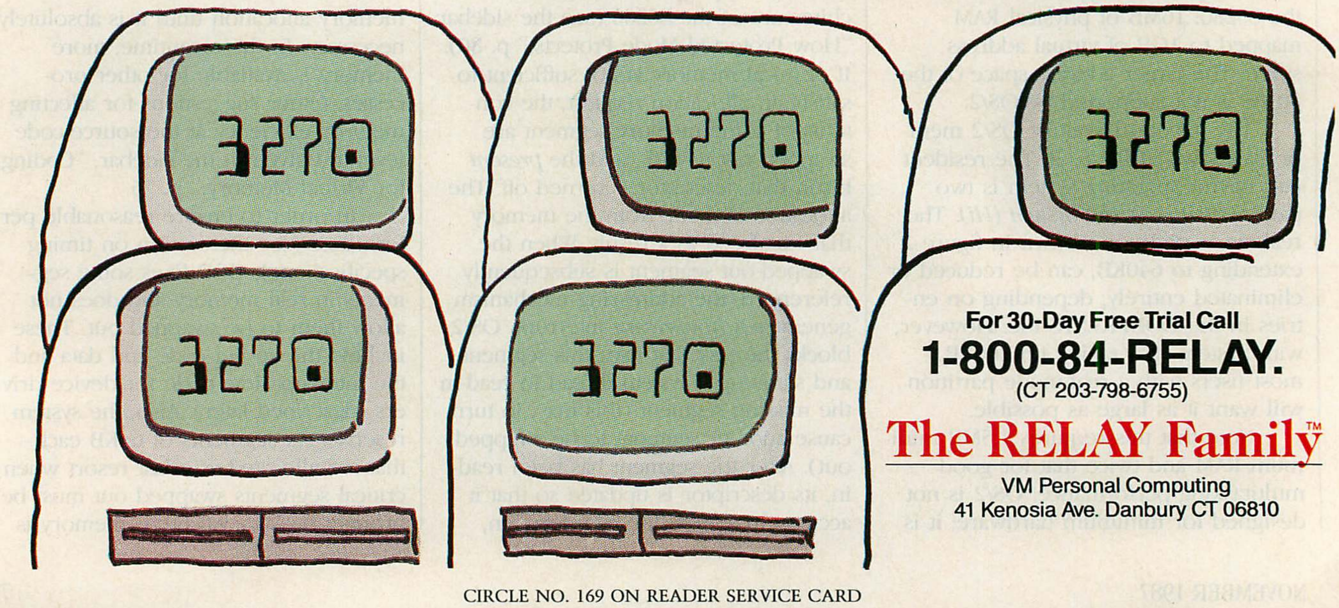

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considered to be available for dynamic allocation and swapping.

OS/2 uses a least recently used (LRU) algorithm to decide what segments to swap out to disk. While this method is not important for most applications, it could, on occasion, affect optimal segment access patterns and segment sizes. The other possible swap-out algorithm, least frequently used (LFU), requires that the system track how often each segment is used, a larger overhead than simply tracking when each segment is used.

Memory allocation and swapping under OS/2 is done on a segment basis, not a page basis. The Intel architecture is basically segment oriented, with segments limited to 64KB each because of the 16-bit size of the 80286 registers. The 80386 has an additional mode that uses 48-bit addresses instead of segment: offset pairs; in this mode it can address up to 4GB of memory in a flat (unsegmented) address space. The 80386 also has hardware to implement page swapping. OS/2 does not support either of these features.

The difference between segment-based and page-based memory management is that a segment's size is determined by the application, whereas page size is determined by the system. A paged virtual memory-management system has only one size page to worry about, which is efficient when a fair amount of swapping takes place. A segment-based virtual memory-management system must track each segment's size and location in RAM or on disk.

While demand page swapping is the virtual memory-management method used in most minicomputer operating systems, including UNIX and VMS, it is not well supported by the 80286 hardware. Since OS/2 is designed to run well on the 80286 while allowing future enhancements for the 80386, the decision that was made to do only segment swapping, for which the 80286 hardware is especially designed, was reasonable.

Besides automatic and transparent virtual memory management, OS/2 provides a wide selection of system calls for memory management by applications. Included are services to allocate and free single segments, allocate "huge" segments over 64KB, subdivide segments into blocks, share segments among processes, and create segments to be written and executed.

Although the 80286 does not directly allow huge segments, OS/2 has its own mechanism for their allocation. When a huge segment is requested, the system allocates several maximum-size segments, creates descriptors for each one, and returns the selector for the first one. To access the next segment, the system returns a selector spacing value that can be added to the base selector to obtain the next selector. Note, however, that the several physical segments making up a huge segment need not be contiguous in memory.

CODING FOR VIRTUAL MEMORY

Because OS/2 performs segment swapping, choice of segment size and access patterns must be a consideration for optimum performance. For instance, hundreds of tiny segments will entail a lot of overhead in memory allocation time and header space—each segment has about 30 bytes of header. On the other hand, if 64KB segments are available for constant swapping, substantial overhead is incurred every time the system performs that 64KB disk transfer.

Controlling the order in which memory is accessed determines the amount of swapping *within* the application. For instance, if two large arrays are in separate segments and the following code is written:

```
for i = 0 to size
  array1(i) = <expression1 > ;
  array2(i) = <expression2 > ;
next i
```

segments will be switched inside the loop and, in the worst-case scenario, both segments might be swapped each time through the loop. On the other hand, if the code is written as

```
for i = 0 to size
  array1(i) = <expression1 > ;
next i
for i = 0 to size
  array2(i) = <expression2 > ;
next i
```

localized access within each segment is guaranteed, instead of flipping between them. Of course, if **array1** and **array2** were in the same segment, the first method would be more efficient than the second, because, in this case, there would be only one set of index overheads in existence.

The above paragraphs provide suggestions for affecting memory efficiency at the source-code level.

—Martin Heller

Because segment allocation incurs substantial overhead, OS/2 has a mechanism for intrasegment memory suballocation, using a classical linked list of storage descriptors. C programmers will recognize this as the same method used by the standard **malloc( )** function provided in most C compiler libraries. The system-level memory suballocation functions of OS/2 give an efficient alternative that can be used by MASM and high-level languages other than C.

Although normally the protection mechanism hides the memory allocated to one process from other processes, in OS/2 memory can be shared in two ways among processes designed to cooperate with one another. One is for the process owning a shared memory segment to pass it to another process whose task identification is known (usually, this means that the sending process created the receiving one). The other is for the owning process to create a named shared segment; then any other process that knows the name can have access to it.

Hardware protection is ideal for preventing accidental attempts to overwrite code or execute data. Situations can arise, however, in which this level of protection is undesirable. Consider the following two cases: it might be necessary to compile a bit of code and run it; then a program loader must perform segment fix-ups before it runs the code. OS/2's response to this is the DosCreateCSALias function, which accepts a data segment selector and returns a code segment selector for the same physical segment.

DOS COMPATIBILITY

OS/2 addresses both sides of the compatibility coin with the DOS environment. In the first place, most well-behaved DOS programs run in the OS/2 real mode. Secondly, programs can be written to run both under DOS and in the OS/2 protected mode.

Real mode (also called *DOS compatibility mode* or the *compatibility box*) can be started as an OS/2 session. It provides a reasonable facsimile of the DOS 3.x environment and includes support for all *documented* DOS 3.3 system services as well as a few commonly used undocumented services. (For instance, Borland's SideKick can be run under OS/2 in real mode, even though it uses undocumented system calls.) The real-mode session is suspended when it is put into the background, since OS/2 expects DOS programs to blithely write directly to video RAM; if they were allowed to time-

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TABLE 1: ***DOS Features in OS/2 Compatibility Mode***

SUPPORTED	NOT SUPPORTED
File sharing (always in effect)	DOS 3.2 Network features
Documented DOS services	Most undocumented DOS services
ROM data area	Reprogramming 8259 interrupt vectors
ROM BIOS interrupt services	Direct calls to ROM BIOS
Hardware interrupts	Realtime clock interrupt
VDI and CON device drivers	Block device drivers
Spooler interrupt (INT 28H)	Some functions of the INT 24H Critical Error Handler
Reprogramming the 8253 clock/timer	Reprogramming the disk controller
Reprogramming the COM ports	Reprogramming the DMA controllers

Although OS/2's DOS compatibility mode closely approximates the DOS 3.3 environment, it does not duplicate it. Programs that rely on unsupported features may run improperly or may not run at all.

share, they would overwrite the screen being used by protected-mode programs. However, starting up a real-mode process does not totally disable multiprocessing; protected-mode programs continue to run in the background when the compatibility box is operating in the foreground.

DOS users will feel at home with OS/2's real mode; however, they must be aware of several differences. Writing directly to the screen is possible, but the DMA ports cannot be reprogrammed. BIOS interrupts are supported, but addresses in ROM cannot be called directly. Interrupt 26H (direct disk write by absolute sector) is supported only to diskettes, not to hard disks. When a real-mode program is suspended in the background, it could lose interrupts, including clock ticks. Therefore, communications programs and programs with timing dependencies probably will fail. Table 1 gives a summary of the DOS features that are and those that are not supported in OS/2 compatibility mode.

A broad distinction also should be made between real mode and *virtual 8086 mode*, an advanced feature of the 80386 that is absent on the 80286. It provides several 1MB memory spaces, each protected from the other, in the virtual address space of the 80386. Each of these spaces can run a real-mode environment such as DOS, and the spaces can execute concurrently. In effect, the 80386 can execute simultaneously in both protected and real modes and can multitask existing DOS applications. OS/2, whose lowest common denominator is the 80286 architecture, does not support this feature—it has only one compatibility box, in the lowest 640KB of physical memory.

The other aspect of compatibility is the running of OS/2 applications under DOS. This is possible if the OS/2 application is written to use only 8086 machine instructions and call only the *Family API*, a subset of the OS/2 system services. After linking, a family application is processed with the OS/2 **bind** utility, adding a *stub loader* and *bindings* package to the executable file.

When a family application is started in protected mode, only the application proper is loaded from disk, and the system calls are fielded by the standard OS/2 API DLL. In compatibility mode and under DOS, the stub loader attaches the bindings to the application and performs the necessary load-time fix-ups so that API calls refer to entry points in the bindings.

The bindings translate OS/2 system API calls to DOS system function interrupts. So, in effect, the bindings are an OS/2 simulator for DOS or a call-based library to the DOS system functions.

A few other restrictions must be obeyed to build a family application. If a family application is to run in real mode, it cannot be bigger than a DOS application; it must fit into 640KB. None of the OS/2 multitasking features can be used, and certain functions must be restricted to subsets—for instance, all the features of DosOpen cannot be used in a family application.

Not every OS/2 function is made compatible between real and protected mode in family applications. The function DosGetMachineMode can be used to determine the CPU mode, and DosVersion to distinguish between DOS and OS/2 (the latter returns 10). Then conditional code can be employed to handle incompatibilities. For instance, the mouse library has no family binding, so sequences such as the following pseudocode are required:

```
CALL DOSGETMACHINEMODE
     (addressof(mode_flag))
if(mode_flag = 0)  /* real mode */
  do INT 33H function
else               /* protected mode */
  CALL MOUxxxx(parameters . . . )
endif.
```

Family applications are somewhat bigger on disk (by 10 to 30KB) than ordinary applications because of the presence of the stub loader and the API bindings. No speed or size overhead exists for a family application in protected mode—the bindings drop off at load time. A modest cost is incurred for running speed, load time, and size in real mode. For compilers, sort packages, or other traditional applications that would like to run in both of these modes and operating systems, family API seems a reasonable approach. Applications that need more memory, multitasking, or a graphics interface will do better with separate executable files for DOS and OS/2.

I/O SERVICES

The API provides a complete set of services for I/O on character and block devices. Subsystems implemented in DLLs put these services into effect, allowing easy enhancement without rewriting the OS/2 kernel.

The video, keyboard, and mouse subsystems generally follow the structure of the corresponding services available under DOS. (DOS does not directly support the mouse, but most vendors supply device drivers that implement a set of functions called via interrupt 33H.) All three subsystems provide significant extensions to what is available under DOS; the best news, however, is that OS/2 video services are much faster than BIOS interrupt 10H. In addition, applications can gain direct access to both logical and physical video buffers; examples are given in "The Flexible Interface," p. 110.

One I/O service that is new to OS/2 is the character device monitor. This background-only task monitors and processes the data stream to or from a character device. One device may have several monitors; in which case each of them passes the data stream (after transforming it, if appropriate) to the next one. This is the OS/2 equivalent of DOS terminate-and-stay-resident (TSR) utilities that hook interrupts (not allowed in protected mode) and can implement keyboard macroprocessors and hot-key pop-up

utilities. As support, the API includes services for writing to the physical screen even from the background.

Monitors can be used for both input and output streams. The print spooler supplied with OS/2 is a monitor that processes the stream of characters sent to the printer.

The OS/2 file system is, for all practical purposes, identical to the one in DOS. Hard disks and diskettes formatted under OS/2 can be read under DOS and vice-versa. A compatible file system is good news if OS/2 and DOS are to be kept on the same hard disk. It is bad news if partitions bigger than 32MB need to be supported. A promised future enhancement, the Installable File System, will break the 32MB barrier; until then, multiple partitions must be used on large disks. The multiple-partitions support is the same as the one in DOS 3.3.

Like other OS/2 services, file system functions are called by name through the standard API. Calls such as DosOpen and DosWrite will be familiar to UNIX or DOS programmers. A major innovation is that file reads and writes can be asynchronous: the system will actually create a thread to do the I/O while the calling process continues to perform other tasks.

A multitasking system, like a network, must control concurrent file access to maintain integrity of data files. In this regard, OS/2 provides the same capabilities as the SHARE option of DOS 3.1 and later versions.

DYNAMIC LINKING

As discussed in the section on system structure, DLLs are important for keeping OS/2 modular and allowing code to be shared by multiple processes. In this section, dynamic linking is explained in some detail.

In a static link, all the target code must be present when the executable is built and incorporated into the .EXE module on disk. This makes the .EXE larger, freezes the target code, and prevents sharing of the target code. With dynamic linking, only a definition record for the target code is present at link time and incorporated into the executable file; the code itself is kept in a separate .DLL file. The target code can be changed at any time without this affecting the .EXE file, the .EXE is smaller, and the target code will be shared automatically among the multiple threads and processes.

When loading a file with calls to DLL routines, the OS/2 loader determines whether the called modules are already in memory; if not, it loads them from .DLL files. Then it resolves and fixes up call addresses, much as the DOS loader does with statically linked code. Loading of dynamically linked code can be either slower or faster than statically linked code: if .DLL code is already in memory, loading is faster; if it must be loaded, the process is slower, since .EXE files are contiguous and .DLL files require library directory lookups.

The .DLL files can be used in a number of special ways to tune application performance. Dynamic linking is simplest at load time, as described above. However, it may not be desirable to have all dynamically linked code loaded at once: there might be rarely used sections of the program requiring the loading of large libraries, which could take the program an unacceptably long initialization time, or the program could have a number of different, mutually exclusive options. In this case, dynamic linking should be done at run time instead of at load time. The routine names would be generated at run time, then loaded with explicit calls to the function DosLoadModule. Afterward, these could be released with calls to the function DosFreeModule.

> *A multitasking system, like a network, must control concurrent file access in order to maintain the integrity of the data files.*

OS/2 automatically takes care of data segments in shared modules. Data specific to a particular process calling a shared module is called *instance data*; memory for it is allocated and values are initialized for each calling process at each call. Data that is common to all users of the module is called *global data* and is initialized only at the point when the module is loaded.

As previously mentioned, OS/2 subsystems are generally implemented as DLLs, which makes them easy to replace, up to a point. Whereas many of the services are performed by routines that execute at privilege level 3, some of the more important ones, such as memory allocation and task control, must be performed at level 0, the kernel. The replaceable portions of these services merely invoke a call gate to transfer to entry points in the kernel.

DEXTEROUS DRIVERS

As discussed in the section on system structure and shown in figure 1, device drivers provide the interface between OS/2 and system peripherals. Here drivers are discussed in moderate detail; full details can fill up at least an entire book. Developers and OEMs who need to write device drivers also should request a supplemental kit (costing $150) that is available from Microsoft to owners of an OS/2 SDK. The kit includes special software that may render debugging protected-mode device drivers merely difficult instead of next to impossible.

OS/2 uses device drivers in much the same way as DOS uses BIOS—as a hardware-dependent layer between the device-independent operating system and the hardware. One obvious difference is that DOS drivers can use the ROM BIOS that comes with the hardware; for their part, the OS/2 device drivers are contained totally in software and may come with either the operating system or the hardware.

For OS/2, the ROM BIOS fulfills only two functions: to start the OS/2 boot-strap loader and to provide services to the DOS 3.x box. Since BIOS code, in general, will not run in protected mode, OS/2 ignores BIOS in protected mode and uses device drivers to go directly to the hardware. The outcome can be good and bad. On the plus side, device drivers are easier to change than BIOS chips. The drawback is that the built-in customization provided by ROM BIOS extensions in devices such as Enhanced Graphics Adapter (EGA) cards no longer exists.

The new IBM Personal System/2 (PS/2) hardware provides a partial correction for this. IBM has added an Advanced BIOS that can work with the device driver in real and protected modes. Although this innovation is not strictly an OS/2 feature, OS/2 can support it when running on a PS/2.

The device driver provides basic services directly to the operating system and indirectly to applications. It performs reads and writes on physical devices and I/O control (such as device resets and mode changes). It also isolates the OS/2 kernel from the hardware; in turn, the kernel isolates the device driver from applications, system structures, and events.

All device drivers have a standard interface. The OS/2 kernel does not know or care whether a given device

uses DMA or programmed I/O, it just asks the device driver to transfer the information. Neither is the kernel concerned with the disks' geometry. On the other hand, the kernel provides a number of services to device drivers, called device helps (DevHelps).

The structure of an OS/2 device driver is similar to that of a DOS driver; there are both strategy and interrupt entry points. But because OS/2 is a multitasking system, this division makes sense at last. The flow of control through a device driver is as outlined in the paragraphs below.

When an application requests a device I/O, it calls the system API; the request reaches the kernel, which blocks the requesting thread, and, in turn, calls the device-driver strategy routine. This routine queues the request, and, if the device is not busy, starts it. The strategy routine then terminates, and control returns to the kernel, which dispatches the next thread.

When the device completes the I/O request, it issues a hardware interrupt that asynchronously preempts whatever thread is executing. The interrupt is handled by the device driver's aptly named interrupt routine, which marks the previous queued request complete, unblocks any threads waiting for this request to complete, and restarts the device with the next I/O request packet in the queue. At the device-driver level, all I/O requests are synchronous, that is, at least one thread always awaits every request. For asynchronous requests from applications, the kernel creates a system thread that waits for completion and signals by resetting a RAM semaphore.

The device driver is an OS/2-format .EXE file on disk, with the same structure as any protected-mode program with dynamic links to OS/2 services. It can have multiple segments in the file, but only the first two, DATA followed by CODE, are kept after initialization. A special header is located at the beginning of the DATA segment that is used for system management. This header is similar to the one used in DOS device drivers; it includes a bit-encoded device attribute word, an offset to the strategy routine, and the name of the device (for a character device driver) or the number of units (for a block device driver). As in DOS, OS/2 device drivers are kept in a linked list in memory.

Although OS/2 allows direct access to API functions from high-level languages, writing device drivers in compiled languages is not practical. The start-up routine inserted by the typical compiler is suitable only for application-level programming, and parameters are passed to the DevHelp routines in machine registers.

A device driver executes in one of the following four modes: *Init, User, Kernel,* and *Interrupt.*

Init mode operates at privilege level 3 with but with I/O privilege. This is operating-system boot time, and it is the device driver's chance to initialize the hardware in a synchronous way, as part of the thread of the system initialization process. As in DOS, the initialization code is called through the strategy routine as an Init request package.

Although OS/2 allows direct access to API functions from high-level languages, drivers are practical only in assembly language.

The driver can hook both hardware and ROM BIOS interrupts and allocate any memory it will need to service I/O requests. To do so, it can use the kernel DevHelp services and a subset of the OS/2 API calls. The initialization code can be discarded once that it has been implemented.

User mode is used for handling real-mode BIOS ROM requests from the compatibility box. Real-mode applications can perform device I/O through the DOS interrupt 21H function interface, through a ROM BIOS interrupt, or through direct access to the device. Requests through interrupt 21H are converted to request packets by the kernel, but BIOS interrupts must be intercepted by the device driver.

Because the ROM BIOS was never intended for a multitasking environment, the device driver must screen requests to the BIOS. First, it must serialize access to the device typically via "device-busy" semaphores. Second, it has to protect critical sections of ROM code from being preempted. For instance, the printer, screen, and disk ROM BIOS service routines are time critical and cannot tolerate being suspended—thus, the device driver has to lock the real-mode session in the foreground while I/O is in progress.

The device driver can hook ROM BIOS interrupts with the SetROMVector device help. It can protect critical BIOS code from being blocked with the ROMCritSection device help function, which will prevent the user from switching away from the real-mode screen. On the other hand, if the user has a TSR application that takes control while the CPU is executing ROM BIOS code with ROMCritSection set, it might not be possible to switch away from the real-mode session until the TSR application is stopped.

Kernel mode is in effect when the device-driver strategy routine (also known as the task-time routine) is called. The strategy routine will not be preempted by a task switch but can be interrupted by incoming hardware interrupts. It must actually protect itself against its own interrupt routine by disabling interrupts when it checks for an active device as well as when it examines the device queue.

The task-time routine should be fully reentrant in order for it to support multiple concurrent requests. Although it will not be preempted, this routine may become blocked (for example, by referring to a segment that was swapped out), or it may voluntary yield control to a time-critical thread. Microsoft suggests checking for a time-critical process every 3 milliseconds and yielding control if one is found. If the task-time routine is suspended for any reason whatsoever, there is, of course, no guarantee that this routine will be resumed before the next request comes along.

The strategy routine is called with a pointer to a request packet, which contains 13 bytes of request header and a variable-length data section. The pointer is bimodal (valid in either real or protected mode) and can be used directly as a 32-bit physical address for linking the request into the queue.

The task-time routine is responsible for queuing request packets and mapping addresses for the interrupt time routine (the reason for this is explained below). I/O control operations are generally done immediately and synchronously; reads and writes are generally queued. It is up to the strategy routine whether queued I/Os are FIFO or sorted by sector: character devices are almost always FIFO, and block devices are often sorted. Sorted block access on disks is sometimes called "elevator seeking."

Interrupt mode refers to the time when the hardware interrupt hands control to the device driver's interrupt entry point. This routine must confirm that the interrupt is indeed for this

driver (in case that hardware interrupts are being shared) and, if this is the case, restart the device for the next I/O request in the queue.

Because the machine mode and addressing context may be different at task time from what they are at interrupt time, device drivers must be *bimodal*, that is, able to operate equally well in both real and protected modes. Because real-mode addresses are, in general, not the same as protected-mode address, segment arithmetic is inappropriate. And, as the contents of local descriptor tables need not remain the same from task time to interrupt time, the storing of segment descriptors also is inappropriate.

The solution is to store only 32-bit physical addresses. There are DevHelp routines to convert physical addresses to and from virtual addresses and user virtual addresses. For instance, the PhysToVirt function converts a 32-bit address to a segment: offset pair in real mode and a valid selector:offset pair in protected mode (creating descriptor-table entries as appropriate). This relieves the device driver from the responsibility of having to do mode-dependent addressing by recognizing the CPU mode. The call, UnPhysToVirt, is used as a signal that the device driver has finished with the temporary selectors that were set up with its calls to PhysToVirt. The VirtToPhys device help is used by the strategy routine to convert the virtual buffer addresses passed by the client routine to the 32-bit physical addresses that will be valid at interrupt time.

Bimodal addressing may seem more like voodoo than programming. But some of the confusing bits are actually simple in practice. For example, suppose that a buffer is in extended memory and an interrupt comes in real mode. The interrupt-time routine cannot access extended memory in real mode, but it does not have to: all it has to do is mark the I/O packet complete, restart the device, and exit.

Other considerations in designing device drivers are that protected-mode objects are usually movable and their location may change between task and interrupt times. DevHelps serve to lock and unlock memory and to allocate and deallocate physical memory. However, tying up too much static memory could increase the number of swapping operations that the system must perform to run applications—this is a trade-off between the extra code to handle moving objects and the overall system performance.

TIMING SPECIFICATIONS

The announced critical OS/2 timing specifications are for a standard 6-MHz AT. All timings should be faster on higher-clock-speed 80286 machines and on 80386 machines. These numbers are targeted by Microsoft for their software and developers should strive to attain them in order to maintain acceptable overall system performance.

Interrupt latency. The maximum time from the occurrence of a hardware interrupt to its acknowledgement by a device driver is 400 microseconds.

Mode switching. It takes a maximum of 1 millisecond to switch from protected mode to real mode on an 80286 machine. Switching back to protected mode is faster; mode switching on an 80386 machine is much faster.

Critical thread latency. The highest-priority thread should have to wait no more than 6 milliseconds from the time that it is unblocked up to the time that it starts running. Thread latency includes, as well, 1 millisecond of possible context switching.

Timer resolution. OS/2 resets the system timer to operate at 32 Hz. Time intervals, although they can be specified in milliseconds, are restricted to the resolution of a timer tick, approximately 32 milliseconds.

In the final analysis, regardless of specifications or any adherence to them, OS/2's performance will be measured in real-world end-user applications. A complete exploration of this subject must await the introduction of significant applications whose performance can be measured.

From all the evidence available, OS/2 constitutes a complicated operating system whose true dimensions will come to light only through actual hands-on experience. Although much remains to be learned about the system, OS/2's capabilities certainly make the effort worthwhile. The three salient features of OS/2 architecture are the following: a design basis that favors interactive response, close optimization to the underlying hardware, and a modular, expandable system structure.

At the moment, the system has (finally!) realized the full potential of the AT-class machine. Although an 80286 machine is hardly state of the art, it represents a quantum leap over the most prevalent personal computer configuration, a wheezing antique of an 8088 CPU running DOS.

OS/2's main attraction, however, is the promise that it harbors for the future. Microsoft has announced that OS/2 is poised to become the bedrock upon which several generations of software for ever more powerful Intel-based machines will be built.

Martin Heller, Ph.D. (physics), is designing applications for OS/2. He consults on technical uses of computers and edits the Journal of Engineering Computing and Applications.

HOW PROTECTED MODE PROTECTS

A review of the principles of hardware protection is important because OS/2 uses protected mode on the 80286. The 80286 hardware design provides protection on three levels.

First, it isolates concurrently running tasks by limiting memory access to a memory space that is separately defined for each task.

Second, it isolates various functions performed within a task by assigning them to one of four privilege levels and enforcing rules for memory access across level boundaries. Figure 1 illustrates the relationship between intertask and interprivilege protection. A code executing at level zero has the highest privilege, which means that it can perform any instruction in the 80286 instruction set and access memory at any level. Code at a less privileged (numerically greater) level cannot execute certain instructions and cannot directly access segments at more privileged levels. The chip designers' intention (honored by OS/2) was that only the kernel should run at level zero, whereas applications run at level three, which has the lowest privilege.

Third, the protection mechanism imposes memory typing to prevent writing over code and executing data. When the memory space is defined (as explained below), every segment is identified as either executable (code) or readable (data). Code segments also can be declared readable and data segments writable, but writable and executable characteristics are mutually exclusive.

The implementation of all three levels is tightly intertwined within the mechanism for generating physical memory addresses.

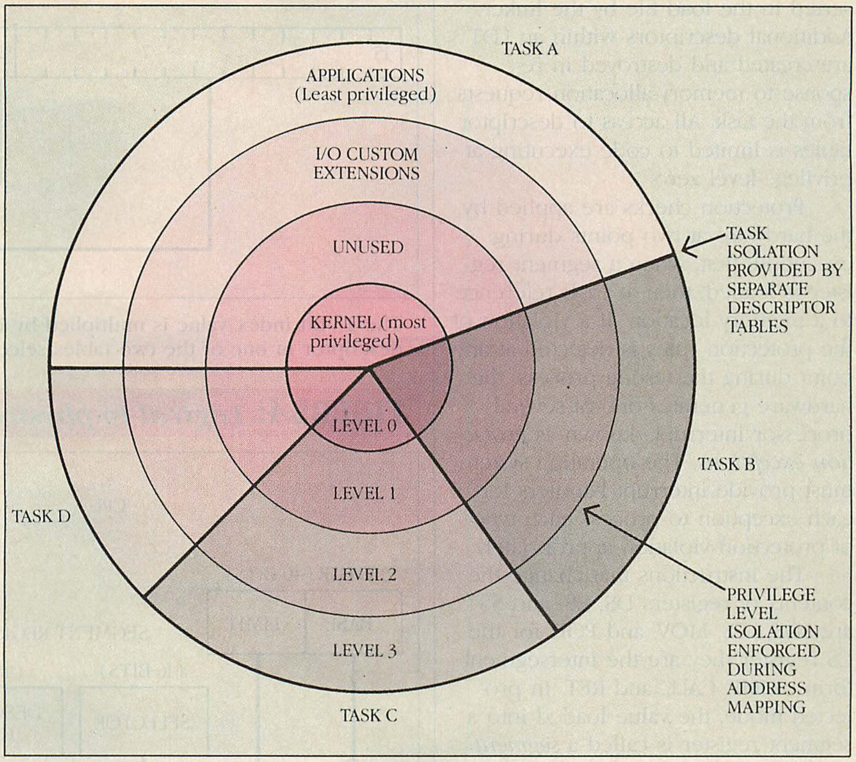
In real mode, the addressable memory space of the 80286 is predefined at 1MB, and any instruction in any program can access any location in this space. In protected mode, the addressable memory space is defined in tables containing a descriptor for each memory segment of 64KB or less. Every task is provided with two descriptor tables: a global descriptor table (GDT) that is available to all tasks in the system and a local descriptor table (LDT) specific to each task. At any given time, only one GDT and one LDT are accessible. Because memory can be accessed only through a descriptor, a task cannot access any memory outside of the space that is defined by its particular pair of descriptor tables.

A descriptor table can be up to 64KB; therefore it can contain up to 8192 eight-byte descriptors, each defining a segment of up to 64KB. With two tables of maximum size, each task can be provided with an addressable memory space of twice 8192 times 64KB, or 1GB (a billion bytes). Of course, the physical memory of the system (limited by the 24-bit address bus to 16MB) limits how many of these segments can be resident in physical RAM at any given time, but, as explained below, a mechanism is available for recording whether a particular segment is or is not resident.

The format of a descriptor is shown in figure 2. The high-order two bytes are solely to provide compatibility with the eight-byte descriptors of the 80386; they must be zero. The 24-bit base address locates the start of the segment in the 16MB physical memory space; the 16-bit limit field holds the length of the segment minus one, or the offset of the last byte within the segment. The access byte specifies the type and privilege level of the segment and whether it is currently in memory. Some descriptors do not define memory segments but contain special pointer values for validating intertask and interlevel control transfers. One type of control descriptor is described later in this sidebar.

Descriptor tables are built in memory, but memory cannot be accessed until descriptor tables are built. In order to break this chicken-and-egg impasse, the GDT is created by the operating system before the switch to protected mode, when the lower 1MB of memory is directly accessible through physical addresses. Furthermore, the descriptor defining the memory for the GDT is kept not in a memory-based table but in a 40-bit GDT register within the CPU. This register holds the 24-bit physical base address and 16-bit length of the GDT; no access byte is needed because the table cannot be swapped out to disk, and its type and privilege (level zero) are invariant. LDTs are created in protected mode, in memory defined by descriptors in the GDT. The operating system builds an LDT for a task at

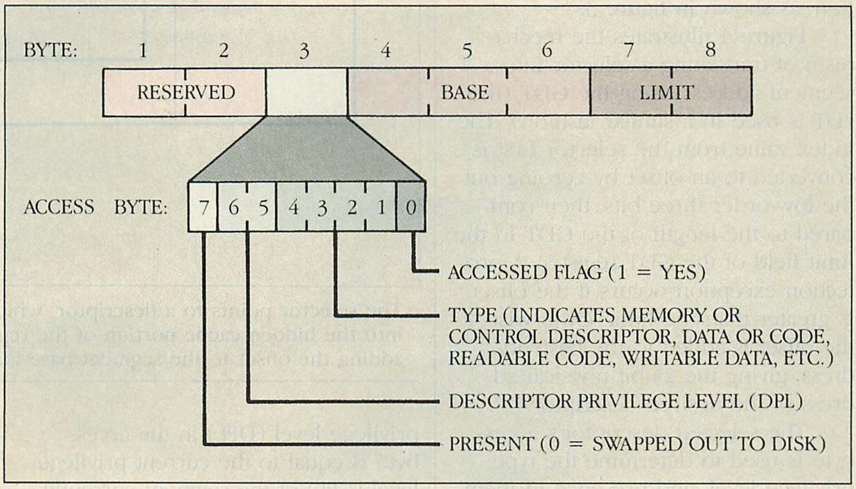
FIGURE 1: ***Intertask and Interlevel Protection***



The protection mechanism totally isolates each task in a separate address space; within each task, it enforces strict rules of interaction between the code and data segments at different privilege levels.

Adapted from Intel iAPX 286 Programmer's Reference Manual

FIGURE 2: ***Segment Descriptor Format***



Only memory defined by segment descriptors is accessible in protected mode (two descriptor tables define a task's memory space). The contents of a descriptor locate the segment in physical memory and validate access.

load time, creating an initial set of descriptors based on information inserted in the load file by the linker. Additional descriptors within an LDT are created and destroyed in response to memory-allocation requests from the task. All access to descriptor tables is limited to code executing at privilege-level zero.

Protection checks are applied by the hardware at two points during execution: first, when a segment register is loaded, then at each reference to a memory location. If a violation of the protection rules is detected at any point during the testing process, the hardware generates one of several processor interrupts known as *protection exceptions*. The operating system must provide interrupt handlers for each exception to process each type of protection violation appropriately.

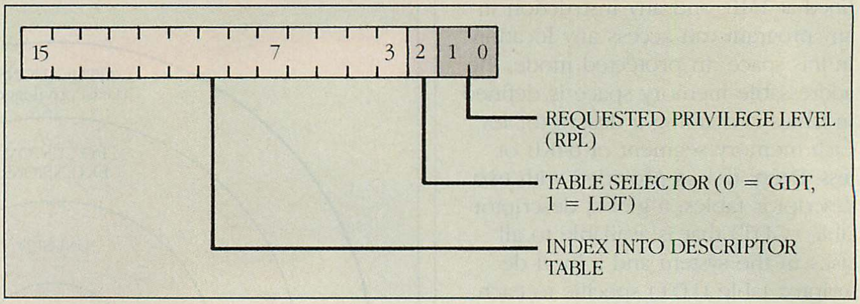
The instructions that change the contents of registers DS, ES, and SS are LDS, LES, MOV, and POP; for the CS register they are the intersegment form of JMP, CALL, and RET. In protected mode, the value loaded into a segment register is called a *segment selector*; it is an index into one of the two descriptor tables available to the task. Because each descriptor is eight bytes long, the low-order three bits of its index are known to be zero and can be used to hold other information, as shown in figure 3.

Figure 4 illustrates the mechanism of translating a selector into a segment address using the GDT (the LDT is used in a similar fashion). The index value from the selector first is converted to an offset by zeroing out the low-order three bits, then compared to the length of the GDT in the limit field of the GDT register. A protection exception occurs if the offset is greater than the limit. Otherwise, the offset is added to the base address, giving the 24-bit physical address of the desired descriptor.

The selected descriptor's access byte is used to determine the type, privilege level, and presence in memory of the target segment. In most cases, the type must indicate a memory, not a control, descriptor (but see a special case below), and the segment must be marked executable for loading into CS, readable for DS and ES, and writable for SS.

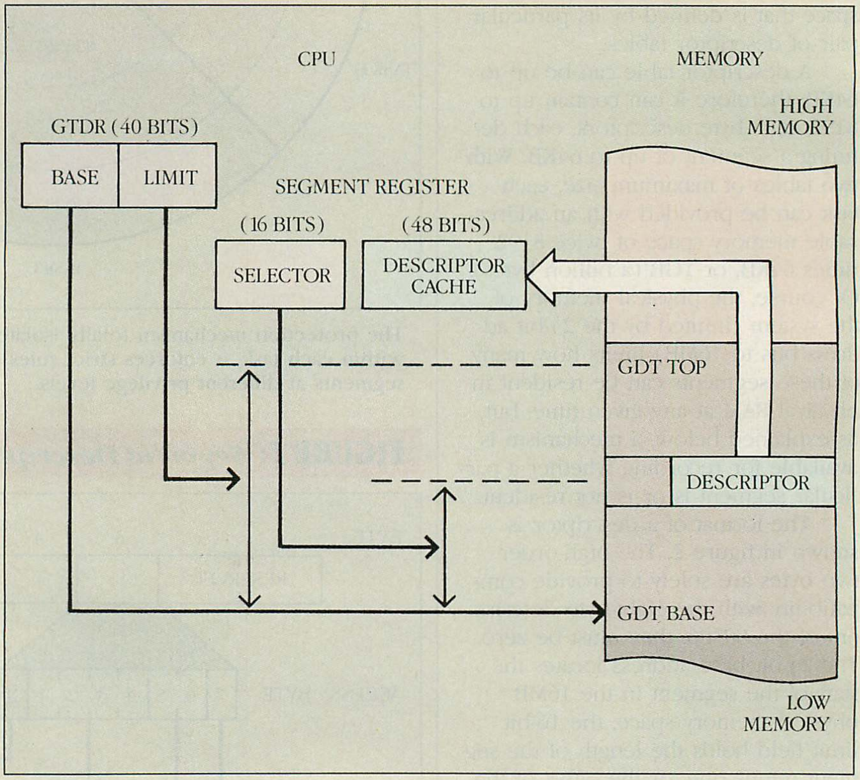
Privilege-level rules are different for loading CS and the other segment registers. For CS, a jump or call instruction is legal if the descriptor

FIGURE 3: ***Segment Selector Format***



The 13-bit index value is multiplied by eight to give an offset to an eight-byte descriptor in one of the two tables selected by bit 3.

FIGURE 4: ***Logical-to-physical Address Mapping***



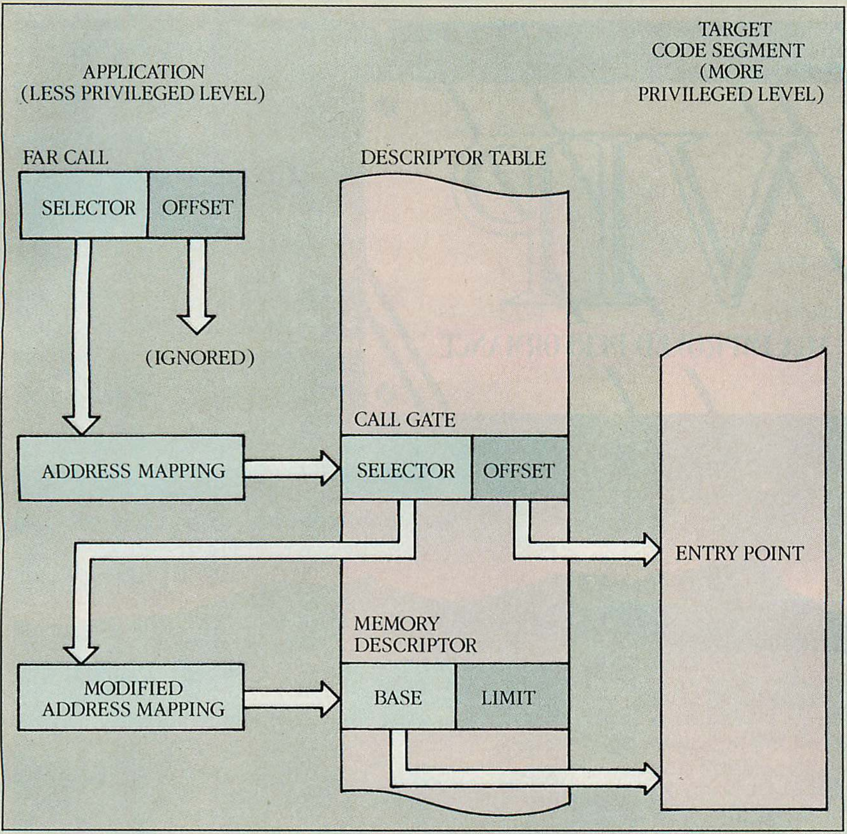
The selector points to a descriptor, which, if it passes certain checks, is loaded into the hidden cache portion of the register. A memory address is generated by adding the offset to the segment base loaded from the descriptor.

privilege level (DPL) in the access byte is equal to the current privilege level (CPL) of the segment currently executing. This means that transfers of control are allowed only within the same privilege level, but a mechanism, (described later) is supplied to allow calls (but not jumps) to more privileged levels. A return is allowed to a level of equal or lesser privilege.

For data and stack segments, the target segment DPL cannot have higher numeric privilege level than the numeric maximum of the CPL and the requested privilege level (RPL) of the new segment selector. This test is intended for the validation of data selectors passed to a routine at a more privileged level; the RPL indicates the privilege level from which the selector originated. In this way, a program at a low privilege level cannot request a privileged program to overwrite privileged memory.

A protection exception occurs if any of the above type or privilege rules are violated. Otherwise, the *present* bit is tested, and a *not-present*

FIGURE 5: ***Transfer through a Call Gate***



A direct call to a procedure in a more privileged segment can be transferred via a call gate with a privilege level similar to the caller's. Level checking is relaxed to allow a call, not a jump, to a segment of higher privilege.

exception occurs if the bit is zero. The hardware does not directly implement virtual memory management, but supports its implementation in the operating system by issuing an interrupt when a missing segment is referenced. The operating system is responsible for turning off the present bit when a segment is swapped out, to keep track of its location on disk and to provide an exception handler that reads the missing segment back in and updates the present bit and base address in its descriptor.

If no exceptions are generated by the type, privilege, and presence checks, the new selector is now moved into the segment register, and the low-order six bytes of the descriptor are copied from the descriptor table into the segment register's descriptor cache. Each of the four segment registers has this 48-bit extension (not accessible by any instructions) that is automatically loaded whenever a valid selector is loaded into the 16-bit part of the register that is visible to programs. Its purpose is to keep the physical segment address and length on-board the CPU so that the subsequent protection checks can be made without reference to any of the tables that are in memory.

Whenever a descriptor is moved to a segment cache, the *accessed* bit in its descriptor in the table is turned on. The hardware neither tests this bit nor resets it when the cache is overwritten; this feature is meant merely to aid the operating system in deciding which segments to swap out by identifying those that were never loaded into segment registers.

Another protection test is applied at each reference to a memory location. The offset portion of the address is compared with the limit value in the cache; a protection exception occurs if the offset if greater. Otherwise, the offset is added to the base value from the cache in order to produce a 24-bit physical address of the location that was referenced.

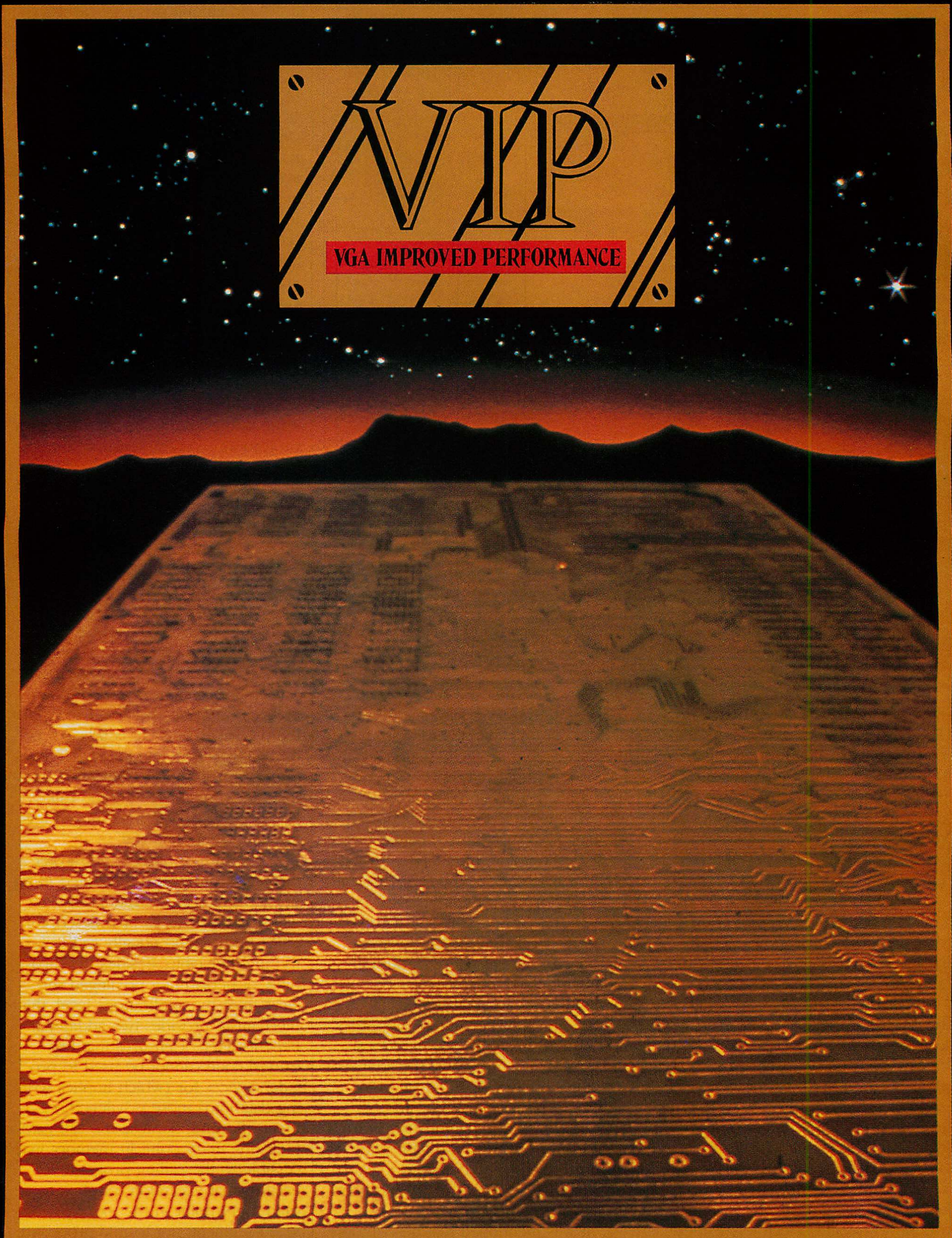
It was mentioned that descriptors not only can define memory segments but also can provide information for enforcing protection when control transfers are required among tasks and among privilege levels.

As described above, the protection mechanism requires that the privilege level of a segment targeted by a far call be the same as the level of the calling segment. But interlevel calls are useful to invoke highly privileged "trusted code" to perform system-level services (such as memory allocation) for applications. An interlevel call is possible, provided that the selector portion of the far-call address points to a control descriptor known as a *call gate*. Its format is similar to that of a segment descriptor (see figure 2), but the base field contains a 16-bit selector instead of a 24-bit base address, and the limit field contains the offset of the entry point called. The call-gate DPL must be the same as the calling-segment CPL, or a protection exception occurs.

When the hardware determines that the target address refers to a call gate and not a memory segment, it performs an additional level of address translation. The selector and offset from the original call instruction are replaced with the corresponding values from the call gate (note that the original offset value is ignored), and a modified address generation process is performed with the new values. This second process follows the same steps as the first, except that the privilege checking is relaxed: no exception is generated if the target segment is at a more privileged level than the segment issuing the call. However, calls to less privileged levels still are not allowed.

The overall process of transfer through a call gate is illustrated in figure 5. Here, the call gate is shown with a selector to its own descriptor table, but it could equally well refer to the other table. Besides the capability of performing privileged services from the applications level, this mechanism provides two additional benefits. First, it ensures that less trusted code cannot be used to provide services for (which implies writing data into) more privileged segments. Second, because the call gate hides the entry point in memory inaccessible to the calling program, it ensures that execution transfers to a valid entry point in the more privileged segment, not to mid-procedure or, worse yet, to mid-instruction.

—TM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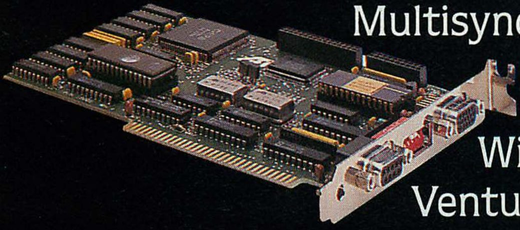

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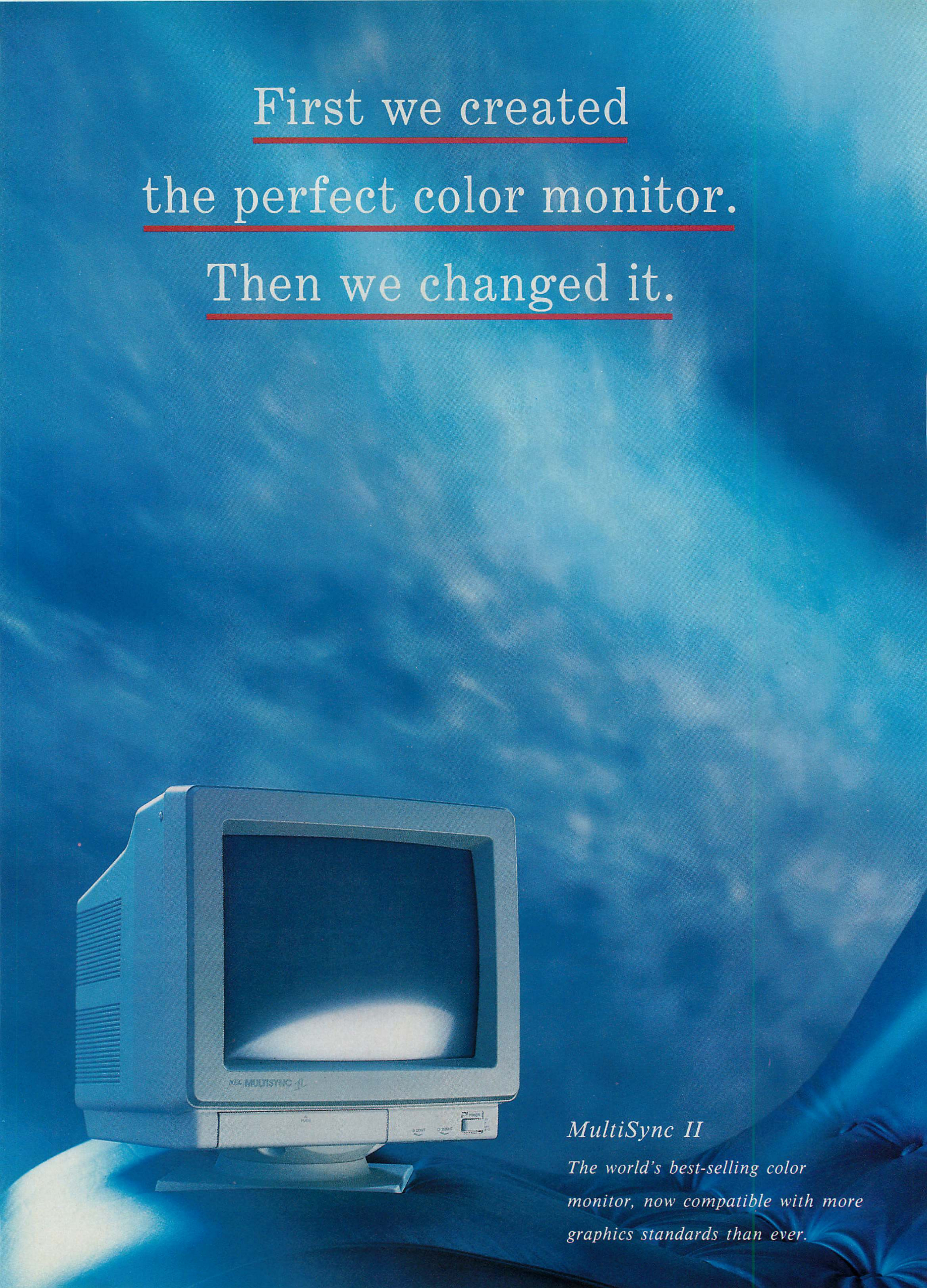
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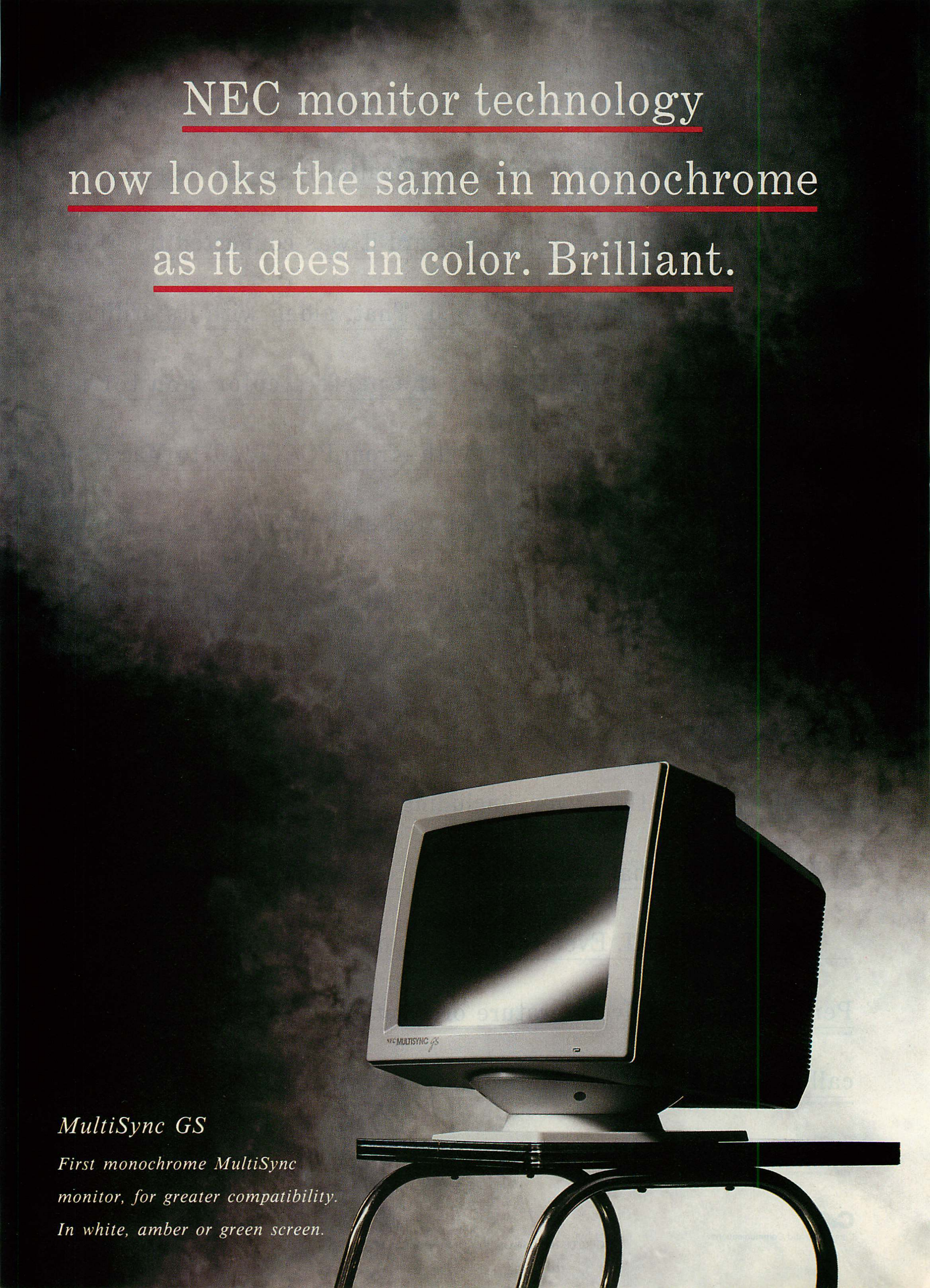
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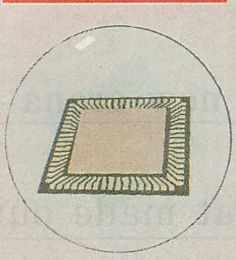


The most heralded feature of OS/2 is its support for multitasking—the ability to run multiple programs concurrently.

Multiple Tasks

STEVEN ARMBRUST and TED FORGERON

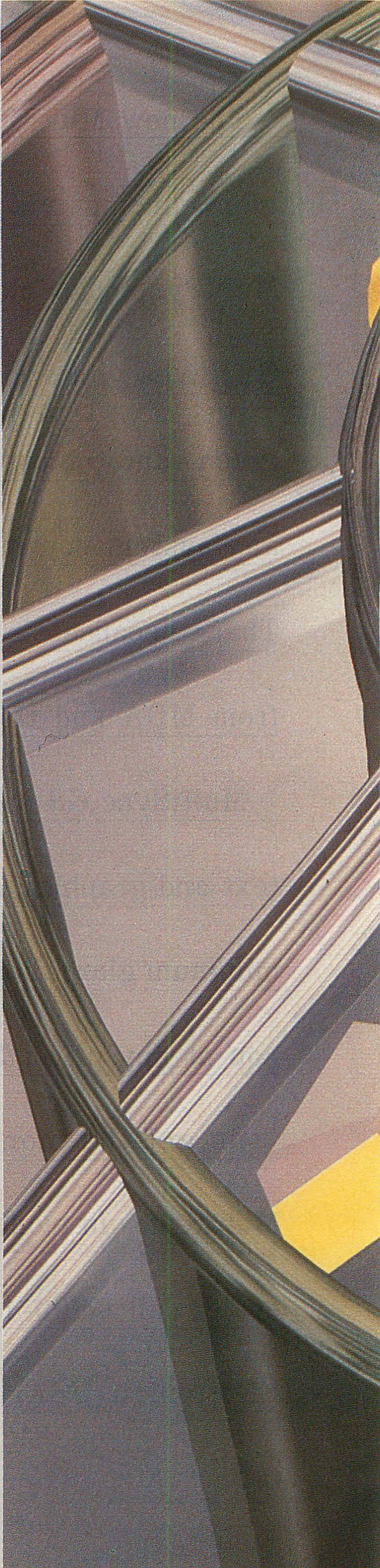
Microsoft has done well to set Operating System/2 (OS/2) apart from DOS with an ability to support multitasking. In a multitasking system, the operating system manages the microprocessor so that all the independent elements appear to be executing simultaneously. Although various multitasking systems have been written for the Intel 8086 family that can operate in the processor's real mode, a protected-mode operating system such as OS/2 has a distinct advantage: the integrity of the system can be guarded by the CPU. This additional protection, however, means that the programs are obligated to use the system's formal methods for communicating with one another; OS/2 provides a cornucopia of such communication methods.

Three types of multitasking are present in OS/2: *sessions*, *processes*, and *threads*. Sessions, the largest overall type, designate what appears on the screen and where input from the keyboard is sent. Processes include programs and their memory resources. Threads are individual multitasking elements. Figure 1 illustrates the relationships among the three types of multitasking; table 1 lists the different functions in each element.

The most visible benefit of multitasking in OS/2 is the Program Selector (see "Enter OS/2," Ted Mirecki, this issue, p. 52). It allows users to create, delete, and switch between multiple sessions. Developers are the primary beneficiaries of the other two types of multitasking: processes and threads. Through multitasking and the associated communication functions, a developer can design an application to increase performance as well as simplify the program design.

SESSIONS

A session, the highest level multitasking element, consists of one or more processes that use the same display screen and keyboard (sessions are also referred to in Microsoft documentation as *screen groups*). For example, a user could start a word processor as one session, a spreadsheet as another, and a database program as a third. Each of these sessions displays information at a logical display and accepts input from a



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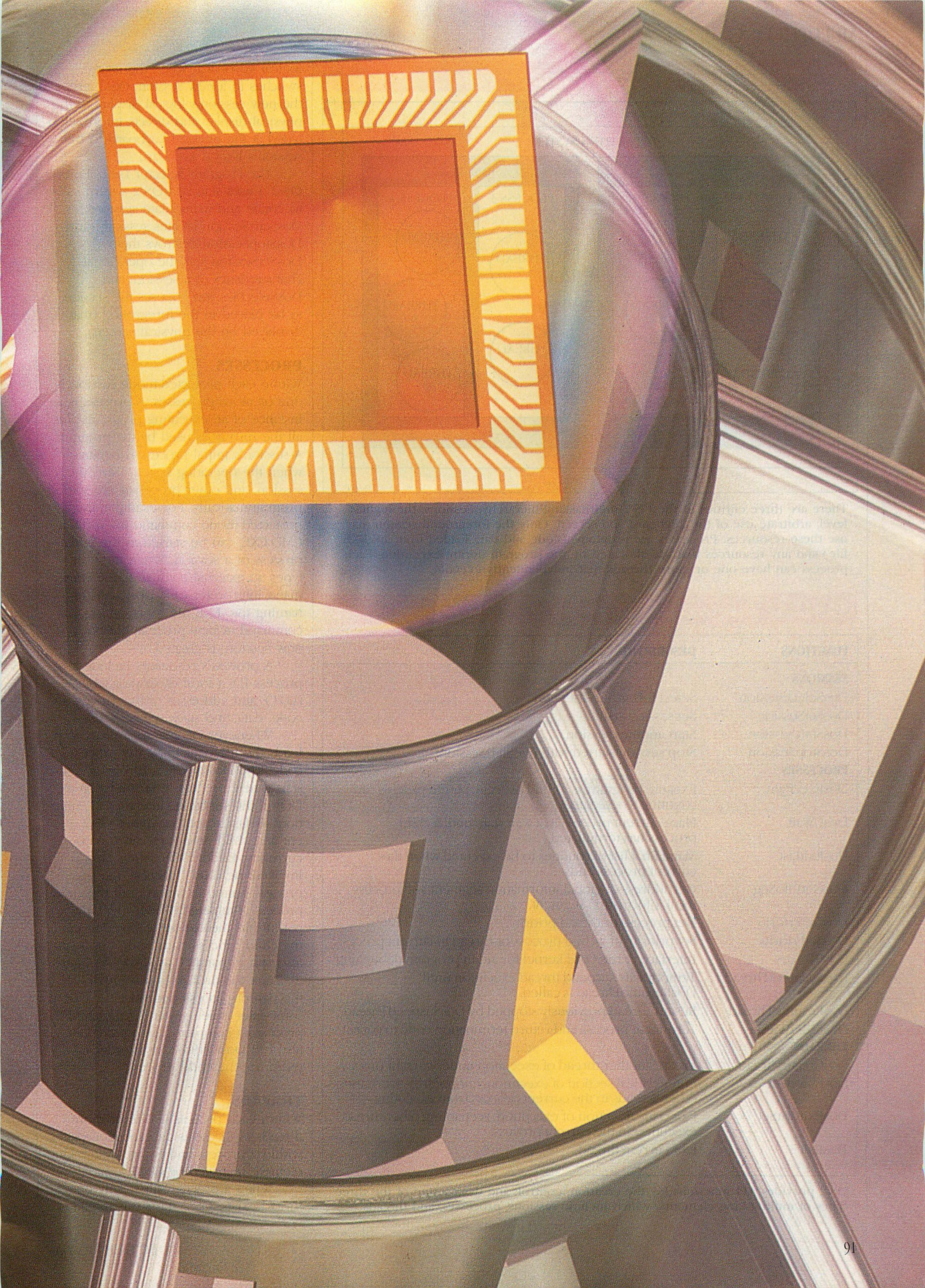
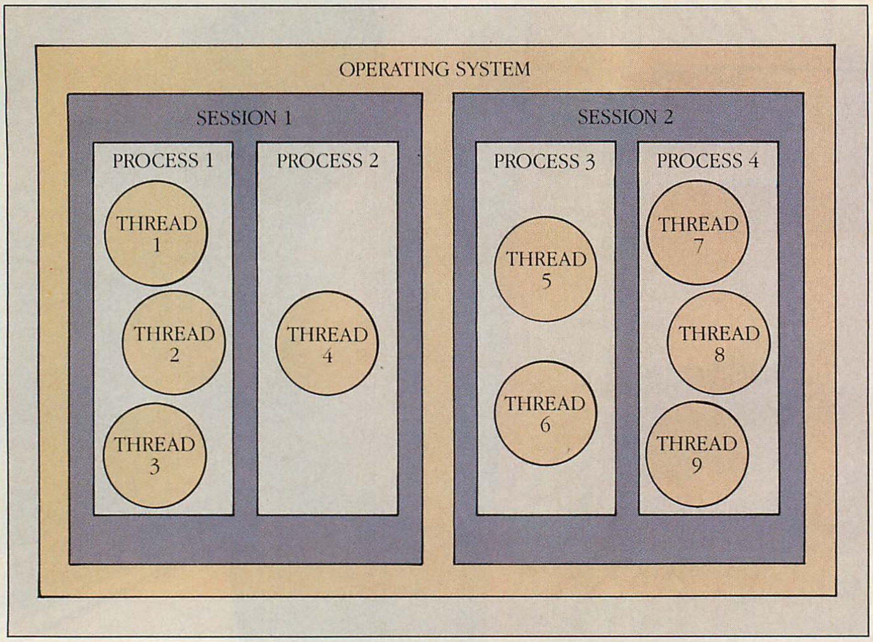


FIGURE 1: ***Sessions, Processes, and Threads***



There are three entities in the OS/2 multitasking hierarchy. Sessions, the highest level, arbitrate use of the keyboard and screen. Only the foreground session may use these resources. Processes are programs (code and data loaded from an .EXE file) and any resources that are allocated by the program during execution. Each process can have one or more threads that independently execute.

TABLE 1: ***Tasking Functions***

FUNCTIONS	DESCRIPTION
SESSIONS	
DosSelectSession	Select foreground session.
DosSetSession	Set session status.
DosStartSession	Start another session.
DosStopSession	Stop session started with DosStartSession.
PROCESSES	
DosExecPgm	Execute program as a child process; parent process can continue to execute.
DosCWait	Place current process in a wait state until a child process has terminated.
DosExitList	Maintain a list of routines to be executed when the current process ends.
DosGetInfoSeg	Get address of global information segment and process local information segment.
DosGetPriority	Get process or thread priority.
DosSetPriority	Set priority of a child process or thread in current process.
DosPTrace	Interface to the OS/2 kernel for aid in program debugging.
DosSuspendThread	Temporarily suspend thread execution until DosResumeThread is called.
DosResumeThread	Restart thread previously stopped by DosSuspendThread.
DosKillProcess	Terminate process and return termination code to parent.
THREADS	
DosCreateThread	Create another thread of execution under current process.
DosEnterCritSec	Enter critical section of execution, temporarily preventing other threads in the current process from executing.
DosExitCritSec	Exit critical section of execution, reenabling other thread execution in the current process.
DosExit	Exit current thread.

OS/2 provides API functions for the creation, control, and destruction of the three types of multitasking elements, which include sessions, processes, and threads.

logical keyboard. When the user switches to a new session, OS/2 writes the new session's logical display to the physical display and directs information typed at the physical keyboard to the session's logical keyboard.

The Program Selector (see "Enter OS/2") uses standard OS/2 system calls to create and manipulate sessions. DosStartSession creates sessions, and DosStopSession destroys them. DosSetSession sets the operational characteristics of a session, and DosSelectSession chooses the session to be placed in the foreground (that is, displayed on the physical screen).

PROCESSES

Within each protected-mode session is one or more processes. A process is an instance of an executing program, plus all the resources used by the program. A session's initial process is begun when the operating system starts the session, and other processes are started programmatically. For example, the protected-mode command interpreter, CMD.EXE, can be started as the initial process of a session. When the user types an external command, the command interpreter calls DosExecPgm, naming the .EXE file representing that command. A new process, but not a new session, is created.

A process's resources include a process ID; a local descriptor table (LDT); and addresses of the process's code, data, and stack segments.

Whenever OS/2 starts a process, it loads the file containing the process's code. The DosExecPgm call is used to start a new process. It is similar to the DOS EXEC function (interrupt 21, function 4BH), except that under OS/2, parent and child processes can run concurrently. Under DOS, when a program invoked the EXEC function, the parent process waited in limbo until the child process completed. Under OS/2, the parent has the option of stopping until the child process completes, but it can also run in parallel, as shown in figure 2. When the processes run in parallel, the parent process can call DosCWait at some later time to wait for the child process to complete. The parent can also call DosKillProcess in order to terminate the child process.

THREADS

Within each process is one or more threads. A thread is an execution path within a process and is the multitasking element managed by OS/2.

When a process starts, only one thread exists. OS/2 starts this thread at

the entry point of the program being executed by the process. This initial thread can start additional threads to gain more concurrency. Instead of invoking a thread with an ordinary procedure call, the initial thread uses the DosCreateThread call. This call specifies the address of the thread (for a call in C, this is the procedure name) and then initiates the procedure as a separate thread. Unless the procedure has been defined in a dynamic link library (DLL), the call does not load any program code from the disk (the program code was already loaded when the process was started).

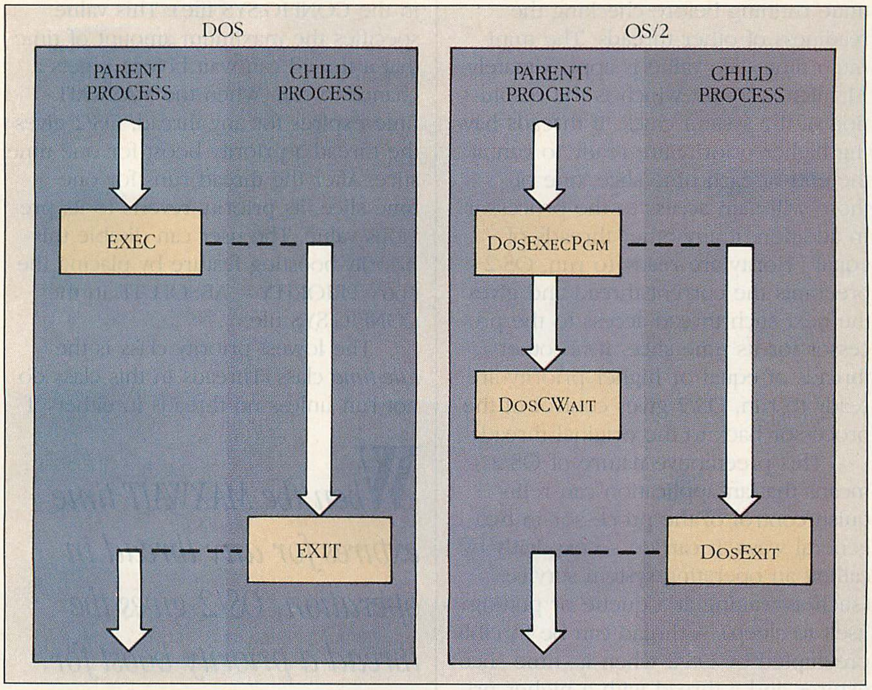
OS/2 supports as many as 255 separate threads (255 per system, not per process or per session). The number that is allowed for any particular system (from 16 to 255) can be set with the THREADS = entry in the CONFIG.SYS file. For each thread, OS/2 maintains a thread priority, a stack, a processor state (copies of all the processor registers), and a thread state (blocked, ready, or active). All other resources are owned by a process and, thus, are shared among all threads in that process. For example, if one thread opens a file and obtains a file handle, another thread in that process can use the file handle to access the file.

Although OS/2 is a multitasking operating system, it has access to only one microprocessor; therefore, only one thread can be executing at any one time. The other threads are either ready to execute or blocked. When the OS/2 scheduler determines that a new thread should run, it saves the contents of all the processor registers into the processor state area for the old thread. The scheduler then loads the registers from the new thread's processor state. This enables the new thread to continue just where it left off the last time the thread was interrupted.

This saving and restoring of processor registers has a serious deficiency when OS/2 is run on 80386-based computers, because it applies only to the 16-bit registers available in the 80286. If OS/2 runs on a 32-bit 80386-based computer, it does not save the extended portions of the 32-bit registers, even though user code is otherwise free to use 32-bit 80386 instructions.

For example, in an 80386-based computer, suppose thread *A* performs a 32-bit operation in order to add the EBX register to the contents of the EAX register. Now suppose thread *A* is preempted by thread *B*, which proceeds to subtract EAX from itself, thereby setting the entire 32-bit register to 0. When

FIGURE 2: ***Comparison of DOS and OS/2 Processes***



In DOS, the parent process must wait until the child process has terminated before proceeding from an EXEC call. In OS/2, the parent can start a child process with DosExecPgm but cannot block its own execution. To synchronize with the child later, the parent can call DosCWait to wait until the child terminates.

thread *A* is restored, its 16-bit AX register is restored, but not the upper 16 bits, which remain set to 0. Therefore, thread *A* has been corrupted. This problem prevents OS/2 from being used with any application that has been designed to use 32-bit instructions.

Processes can have multiple threads running the same code. This is done by invoking DosCreateThread multiple times with the same start address. Each of the threads will have its own stack, but because the threads have access to the same memory, they must take precautions when using static variables and data structures. Mechanisms for intertask communication, such as RAM semaphores, can be used to prevent other threads from accessing these common areas until the first thread is finished. In addition, a thread about to execute a critical section of code can call DosEnterCritSec to prevent all other threads in the process from executing until the thread calls DosExitCritSec. Since DosEnterCritSec does not prevent threads in other processes from running, this command is not an appropriate method for interprocess synchronization.

The DosSuspendThread call and the DosResumeThread call can be used by a thread to suspend and resume execution of another thread in the same process. DosGetPriority and DosSetPriority can be used to get or set the priority of a thread.

SCHEDULING THREADS

Because only one thread at a time can be executing in the system, OS/2 uses a preemptive, priority-based approach for determining which thread will be running at any given time. When created, each thread is assigned a priority class as well as a priority number. This combination determines the overall priority of the thread. At all times, the highest priority ready-to-run thread has access to the processor. When the highest priority thread becomes not ready (when it is waiting for I/O, when it puts itself to sleep for a while with the DosSleep call, when it is waiting to synchronize with another thread, or when its time slice expires), OS/2 gives the processor to the next highest priority ready-to-run thread. When a higher-priority thread becomes ready again (when the I/O operation finishes, when its sleep time is over, or when it receives synchronization from another thread), the lower-priority thread relinquishes control of the processor.

OS/2 uses time-slicing to ensure that threads of equal priorities all have a chance to run. The time-slice value, specified with the TIMESLICE entry in

the CONFIG.SYS file, designates how long OS/2 will allow a thread to continue running before checking the readiness of other threads. The minimum time-slice value is approximately 31 microseconds, which is the resolution of the system clock. If threads having higher priority are ready to run at the end of each time slice, one of those will gain access to the processor. In addition, if any other threads of equal priority are ready to run, OS/2 preempts the current thread and gives the next such thread access to the processor for its time slice. If no other threads of equal or higher priority are ready to run, OS/2 gives control of the processor back to the original thread.

This preemptive nature of OS/2 means that an application can relinquish control of the processor in two general ways. It can do so explicitly by calling an operating system service (such as waiting at a queue or putting itself to sleep). A thread can be forcibly preempted by OS/2 when its time slice expires and a thread with a higher priority is ready to run.

If no other thread wants the processor, interrupting a thread doing useful work would waste CPU cycles. To moderate the overhead from scheduling, an option is available in the CONFIG.SYS file to reduce the frequency of time-slice interruptions conditionally. The TIMESLICE entry has two parameters (TIMESLICE = x,y). The first parameter is the length of a thread's initial time slice. The second is the maximum time slice permitted. If a thread uses its entire time slice without being preempted by a higher priority thread, OS/2 increases its time slice by one clock tick. This continues up to the maximum time slice value.

Thread priority has three classes, each of which has 32 priority levels (0 through 31). The highest priority class is the *time-critical* class. All the threads in this class are of higher priority than the threads in the other two classes. Typically, the threads in this priority class would be those that handle time-sensitive areas, such as servicing high-speed data communications devices.

The next highest class is the *regular* class (also called the *normal* class in some of the Microsoft documentation). This class is used by most of the application programs and OS/2 commands invoked from the keyboard.

By default, OS/2 provides additional scheduling features within the regular class to ensure that all the threads in the class get a chance to run. Associated with the regular class is a maximum wait value (specified in units of seconds by the MAXWAIT entry in the CONFIG.SYS file). This value specifies the maximum amount of time that a thread can wait before it gets a chance to run. When the MAXWAIT time expires for any thread, OS/2 gives the thread a priority boost for one time slice. After the thread runs for one time slice, its priority reverts to its previous value. The user can disable this priority-boosting feature by placing the entry PRIORITY = ABSOLUTE in the CONFIG.SYS file.

The lowest priority class is the *idle-time* class. Threads in this class do not run unless no threads in either of the other two classes are ready to run. The idle-time class is typically used for programs such as print spoolers, automatic disk back-up programs, or any other background-running program.

When the MAXWAIT time expires for any thread in operation, OS/2 gives the thread a priority boost for one additional time slice.

DIVIDING APPLICATIONS

Although three levels of multitasking entities—sessions, processes, and threads—can be created, it is not always clear how to divide a single application into these elements. Should an application consist of a single session with a single process and multiple threads? Should there be multiple processes with one or more threads in each? Or, should the application consist of multiple sessions?

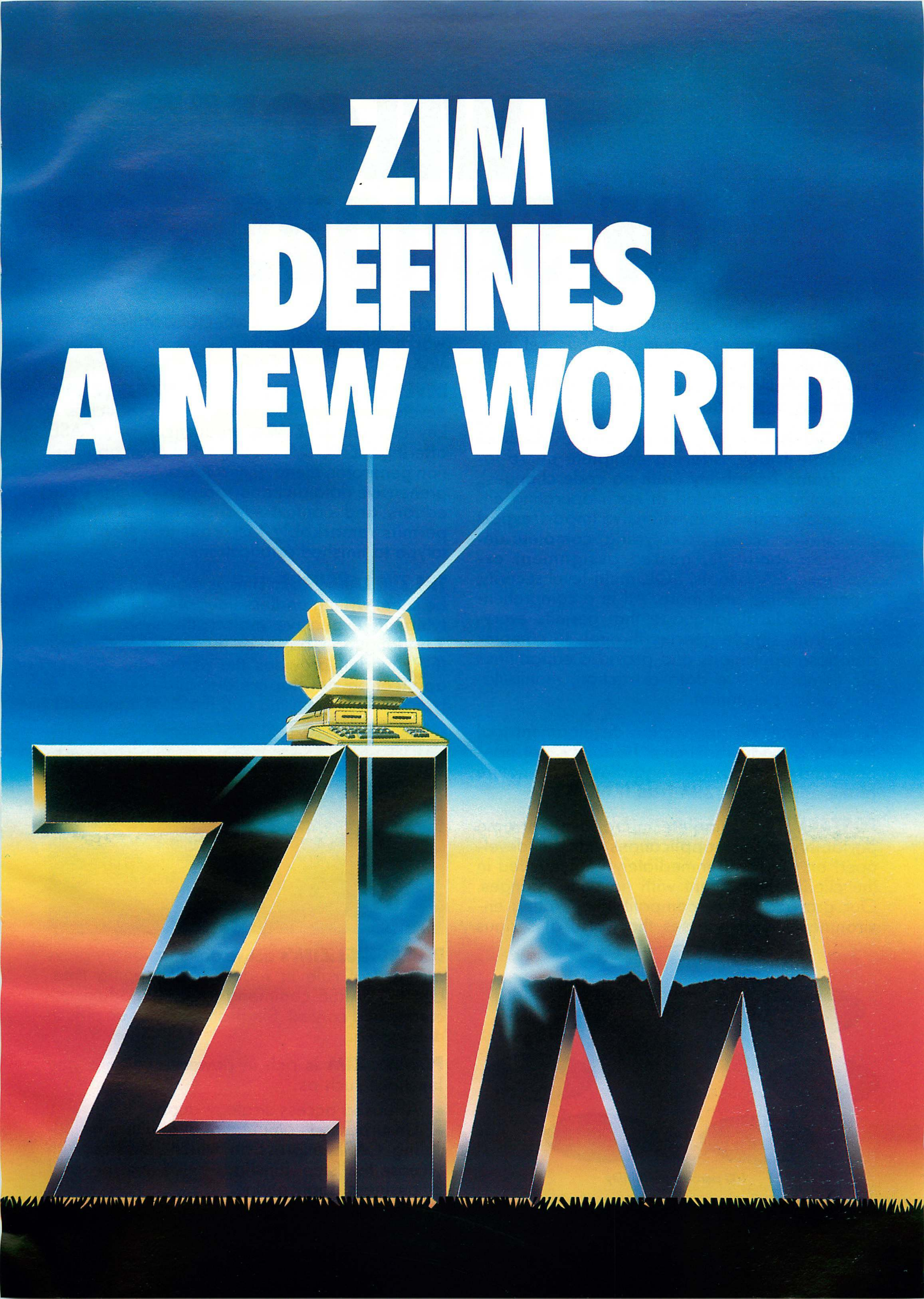
These questions are not answered easily, but programmers can follow some of these guidelines:

- Rarely will an application need to be divided into multiple sessions. The only obvious example of a program that needs to create multiple sessions is OS/2's Program Selector, which creates a shell for invoking multiple applications. Even OS/2's Presentation Manager will consist of a single session, because it allows multiple programs to share the same screen.
- Multiple processes are appropriate if an application has multitasking elements with a high degree of independence or those that need to be protected from one another. For example, a database management application could be divided into a user interface process that handles requests and a background transaction process that supervises the database. This arrangement allows the user interface process to be started, stopped, or killed (for example, through Ctrl-Break) without compromising the integrity of the database.
- If there are many small components that execute for only a short period of time, multiple threads are a better solution than multiple processes because process creation carries a larger overhead than thread creation carries. Creating a process involves loading an .EXE file and then creating the OS/2 kernel data structures such as the LDT. The procedure for creating a thread is much quicker.
- If there are multitasking elements that need to be tied together as closely as two procedures are, they should be assigned as multiple threads in a process. Threads in the same process can typically share data with much less overhead than threads in different processes.
- A separate thread can be used for performing any operation that would block a process when there is useful work to do. For example, a new thread could be created to open a file, which will typically block while the disk is accessed to find the file. Meanwhile, the original thread could perform other work while the new file is being opened.

INTERPROCESS COMMUNICATION

In any multitasking system, mechanisms must be available for the independent elements to synchronize and communicate with each other. In OS/2, each thread runs as if it owned the entire processor. However, threads often need to pass information to one another or to make certain that one thread has completed its operations before another thread starts operation. These mechanisms are especially useful between threads in different processes, because processes are normally isolated from each other by virtue of the processor's protected mode.

OS/2 provides the following interprocess communication (IPC) mechanisms: *semaphores*, *pipes*, *shared memory*, *queues*, and *signals* (see table 2). In most cases, IPC requires the processes to agree upon the names and locations of the resources. Therefore, the processes must be designed and coded specifically to communicate with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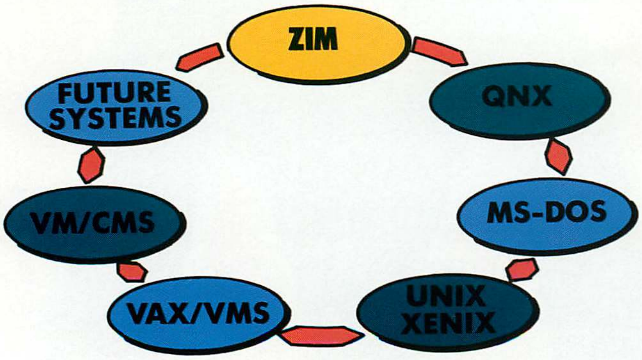

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SQL:
```
SELECT *
FROM WORKONTAB, PROJECTS, EMPLOYEES-
WHERE WORKONTAB.ENUM=EMPLOYEES.ENUM-
AND WORKONTAB.PNUM=PROJECTS.PNUM-
AND PROJNAME='ALPHA'
```

ZIM:
```
LIST ALL EMPLOYEES WORKON PROJECTS WHERE
PROJNAME='ALPHA'
```

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- Unsurpassed computational abilities, including CASE expression which handles with ease the 'step' functions found in real-world business applications.

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- Natural multi-user features including user-defined transactions, roll-back, audit trails and roll-forward.
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SECURITY: **ZIM's** multi-level security features include log-in, passwords, permission-based access to entity sets, relationships and fields and encryption/decryption of entity sets and relationships.

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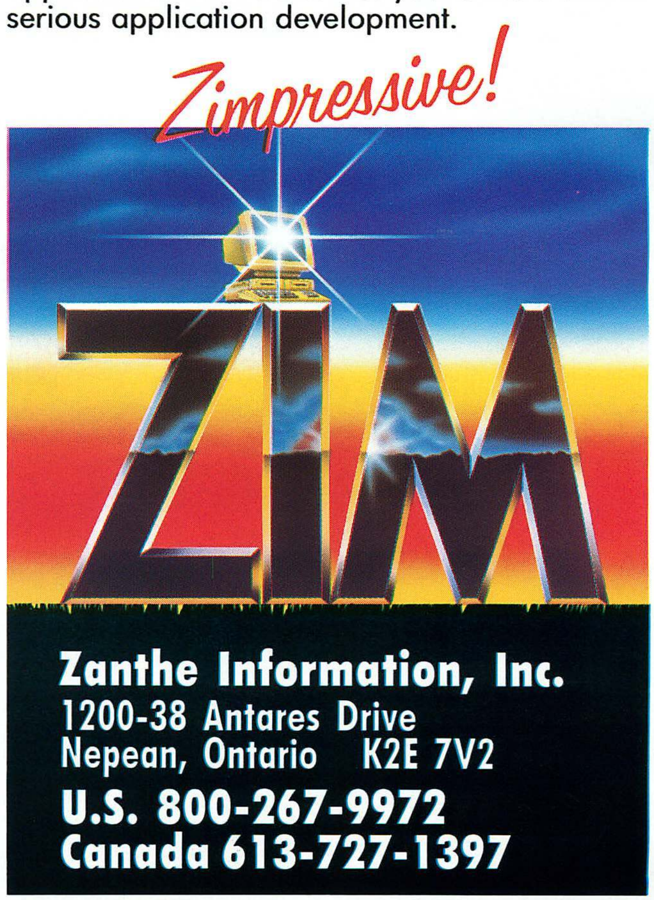

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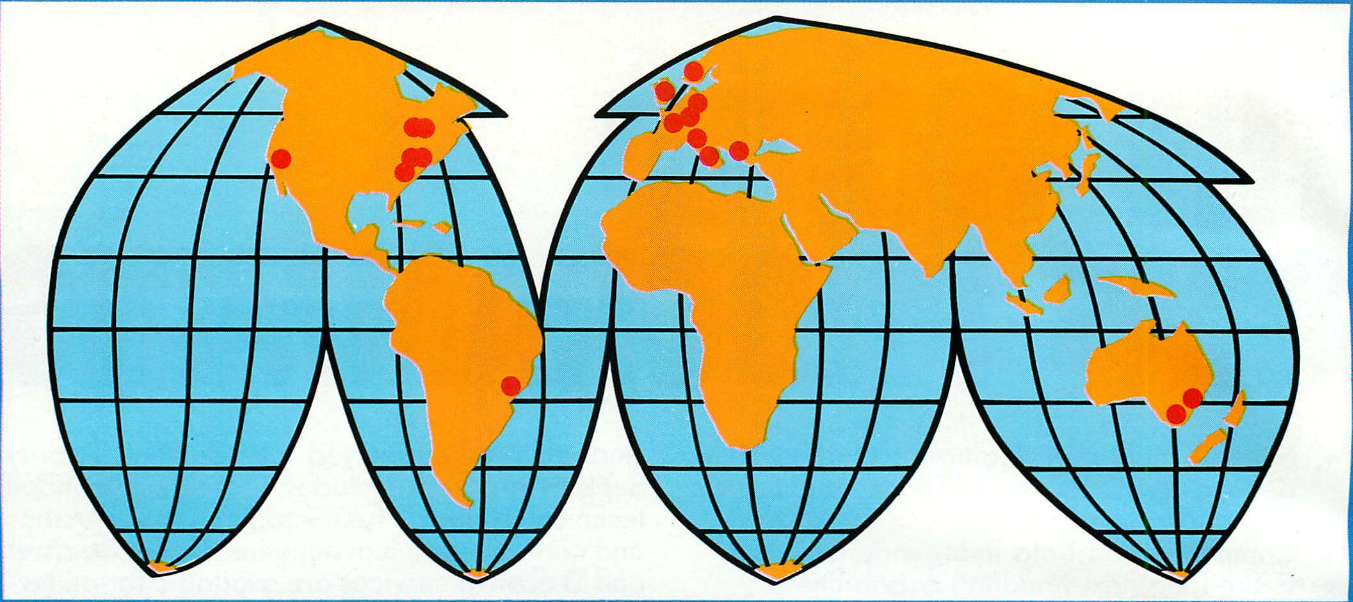

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each other. The exception is the pipe, which allows transparent communication modeled after file I/O.

SEMAPHORES

Semaphores are simple objects that threads can use to coordinate access to resources or to synchronize with one another. Semaphores have two states: owned and not-owned (or, depending on how they are used, set and cleared).

To coordinate access to resources (such as a sensitive area of data), a semaphore can represent ownership of the resource. To do this, all threads must adhere to the convention that before any thread can access the critical resource, it must first request ownership of the semaphore by means of the DosSemRequest call. If it is not owned when DosSemRequest is issued, the issuing thread becomes the owner and can use the resource at will. When the owning thread finishes using the resource, it calls DosSemClear in order to release the semaphore.

If a thread calls DosSemRequest to request a semaphore that is already owned, one of three things can happen (depending on the options the thread specified in the call): the call can wait forever for the semaphore to become clear; it can wait a specified number of milliseconds; or it can not wait at all. In the first case, the thread is put on hold until the semaphore becomes available. In the second case, if the semaphore becomes available in the specified amount of time, the calling thread becomes the owner of the semaphore. Otherwise, the call returns without gaining ownership of the semaphore. In the third case, the call returns immediately, indicating if the semaphore is currently owned.

Multiple threads can request ownership of the same semaphore. If the threads choose to wait (instead of returning immediately), the ones that do not immediately gain access to the semaphore continue to wait until the owning thread releases the semaphore. When this happens, the waiting threads are dispatched again, and the highest-priority waiting thread becomes the new owner, even if a lower-priority thread has been waiting longer. The other threads continue waiting. If equal-priority threads are waiting, the thread that has been waiting the longest becomes the new owner.

Using a semaphore to represent ownership of some resource enables threads to read or write sensitive data areas without fear that other threads will interrupt them before they finish.

TABLE 2: ***Communication Functions***

FUNCTIONS	DESCRIPTION
SEMAPHORES	
DosCreateSem	Create a system semaphore.
DosOpenSem	Open an existing system semaphore.
DosCloseSem	Close a system semaphore.
DosSemRequest	Obtain ownership of a semaphore.
DosSemSet	Set an owned semaphore.
DosSemClear	Unconditionally clear (or releases) a semaphore.
DosSemSetWait	Set a semaphore and wait for it to be cleared (blocks the current thread until the next DosSemClear occurs).
DosSemWait	Wait for a semaphore to be cleared.
DosMuxSemWait	Wait for one of a number of semaphores to be cleared.
PIPES	
DosMakePipe	Create a pipe.
SHARED MEMORY	
DosAllocShrSeg	Allocate a shared memory segment (named) to a process.
DosGetShrSeg	Enable a process to access a named shared memory segment allocated by another process.
DosAllocSeg	Allocate a segment of memory.
DosGiveSeg	Give access to a segment.
QUEUES	
DosCreateQueue	Create a queue.
DosOpenQueue	Open a queue for the current process.
DosWriteQueue	Add an element to a queue.
DosReadQueue	Read and remove an element from a queue.
DosPeekQueue	Retrieve but do not remove an element from a queue.
DosQueryQueue	Return the size (number of elements) in a queue.
DosPurgeQueue	Purge a queue of all elements.
DosCloseQueue	Close a queue.
SIGNALS	
DosSetSigHandler	Define a routine to handle a signal.
DosFlagProcess	Set a process external event flag in another process.
DosHoldSignal	Disable or enable signal processing for current process.

The OS/2 abundance of interprocess and thread communication functions provides a good simplicity-versus-performance trade-off for many applications.

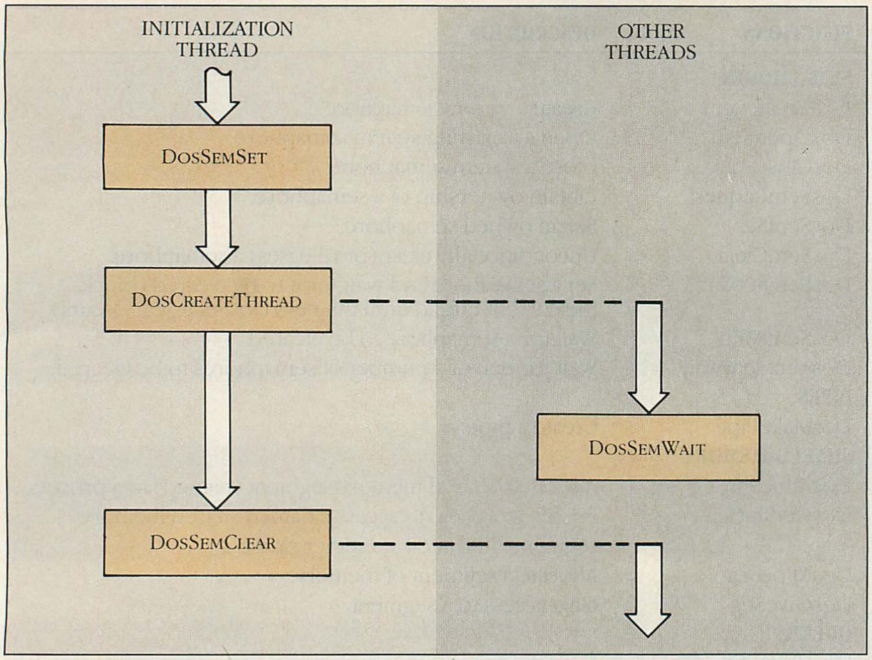
Suppose that one thread gathers information about the positions of aircraft and records their *x*, *y*, and *z* coordinates in a database. Another thread reads the database and displays the aircraft positions on a screen. Without a semaphore guarding the database, the thread that writes the coordinates could write an airplane's *x* and *y* coordinates but then could be interrupted by the reading thread before updating the *z* coordinate. If this happened, the display produced by the reading thread would not represent the airplane's actual position. The same sort of situation could happen if the reading thread was interrupted before it read all three coordinates. Using semaphores, each thread requests ownership of the semaphore before reading or writing the database. Each would clear the semaphore after accessing the database to give other threads a chance in order to use or modify the data.

Another use of semaphores is synchronizing thread activities. In this situation, a semaphore can be either set or cleared. For example, suppose a process consists of an initialization thread plus several other threads. The initialization thread must run first in order to set up the data structures needed by the other threads. After it completes those activities, however, all the other threads are free to run.

To manage this activity, the initialization thread would call DosSemSet to set the semaphore. This would designate that the initialization activity was still under way and that the other threads could not run. When the initialization thread completed its activity, it would call DosSemClear in order to clear the semaphore.

The other threads that depend on the initialization thread to finish its activities would call DosSemWait before doing anything else. This call causes

FIGURE 3: *Synchronizing with Semaphores*



Before starting one or more threads, a master thread sets a semaphore to indicate that initialization is not complete. The other threads call DosSemWait to wait for the "initialization complete" indication. Once the master thread has finished initialization, it clears the semaphore; all of the other threads are now able to run.

the threads to wait until the semaphore is cleared before proceeding. Like the DosSemRequest call, DosSemWait allows the threads to wait forever, for a specified period of time, or not at all. Unlike the DosSemRequest call, all the waiting threads are notified when the semaphore is cleared, not just the first thread on the waiting list. In addition, the DosSemWait call does not transfer ownership of the semaphore when the semaphore is cleared. Figure 3 illustrates the use of semaphores in synchronizing thread activities.

Two additional OS/2 calls are available for use with semaphores in synchronizing the activities of threads. DosSemSetWait is like DosSemWait except that it sets the semaphore first before waiting for it to be cleared. This call can be used if the waiting thread knows that the thread it is waiting for will not get a chance to run first. It guarantees that the semaphore will be set so that the thread can wait for another thread to clear the semaphore. The other call, DosMuxSemWait, is also similar to DosSemWait, but it enables a thread to wait until any one of a number of semaphores is cleared.

OS/2 defines two kinds of semaphores, *system* semaphores and *RAM* semaphores. System semaphores are used for communication between threads in different processes. RAM semaphores are used by threads in the same process. The difference between the two is in how they are created and accessed, but system semaphores also provide a few more features.

In a single process, threads can share memory; therefore, threads do not need to perform a complicated procedure to create a semaphore. Instead, a double-word can be defined as the location of the semaphore and initially set to zero (meaning cleared and unowned). Threads then use the address of that double-word as the semaphore's handle in calls that manipulate the semaphore. For example, if a thread wants to establish ownership of the RAM semaphore, it simply calls DosSemRequest and specifies the address of the double-word representing that particular semaphore.

The use of RAM semaphores depends on threads being able to access the memory containing the semaphore. When two threads are in different processes, they cannot access each other's memory unless they explicitly cooperate to share a memory segment. Thus, a different mechanism must be used.

System semaphores use a named approach for creating and accessing semaphores. This mechanism is almost exactly like the one used for creating and accessing named files. To create a system semaphore, a thread calls DosCreateSem and gives an ASCII name. In response, OS/2 returns a handle that the thread can use in other calls to manipulate the semaphore.

When other threads want to use the system semaphore, they must first call DosOpenSem, specifying the ASCII name of the semaphore. If the semaphore is available, OS/2 returns a handle they can use for other semaphore calls. When a thread finishes with a system semaphore, it calls DosCloseSem to close the semaphore. When all threads that used a system semaphore close it, OS/2 automatically deletes the semaphore. Figure 4 shows how two processes can use a system semaphore.

OS/2 maintains a directory to keep track of system semaphores. This directory is called SEM and is kept in memory rather than on disk. Whenever threads refer to system semaphores by name, they must include the \SEM\ as part of the name, just as in I/O calls a full path name is often used. Thus, the format of a system semaphore name is

\SEM\NAME.EXT

where the rules for defining NAME.EXT are the same as the rules for defining the names of files.

Although a RAM semaphore placed in shared memory might seem to offer the same functionality as the system semaphore, some subtle differences can become important. OS/2 maintains information about the current owner of a system semaphore. If a process exits and still owns a system semaphore, OS/2 will notify any threads in other processes that are waiting on that semaphore by waking them and returning an error code indicating that the semaphore owner has exited. The RAM semaphores gain their simplicity by forgoing this safety mechanism.

PIPES

Pipes are another kind of object that threads in different processes can use to communicate with one another. A pipe is simply an area of memory used to store data—a circular buffer that is a RAM substitute for a file. Figure 5 illustrates the use of a pipe.

Using a pipe is very much like using a file. One thread writes information to a pipe using ordinary I/O calls, and another thread reads the information, again using ordinary I/O calls. Often, threads that communicate via pipes are not even aware that they are using pipes instead of files.

A thread creates a pipe by calling DosMakePipe and specifying the size of the pipe desired. A pipe is limited in

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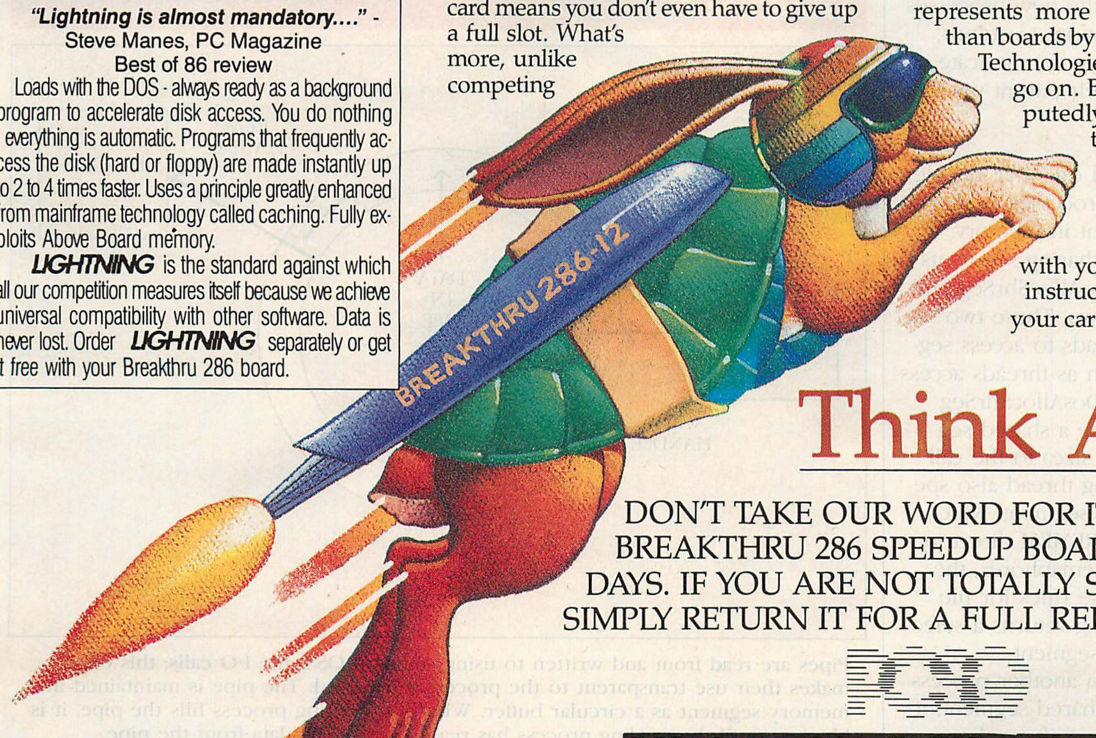

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size to 64KB (minus 32 bytes for the pipe header). This means that the maximum message that one thread can send to another via a pipe is 65,504 bytes. However, a pipe is a circular buffer. Therefore, once the reading thread reads some of the information from the pipe, the writing thread can continue writing data.

In response to the DosMakePipe call, OS/2 returns two handles to the pipe: the read handle and the write handle. Threads can use ordinary I/O calls to access the pipe (DosRead together with the read handle and DosWrite together with the write handle). If a thread attempts to write to a pipe and the pipe is full, the thread is suspended until another thread reads enough information from the pipe to enable the first thread's data to be written. Likewise, if a thread attempts to read a pipe and not enough data exist to satisfy the request, the thread is suspended until another thread writes additional information to the pipe. When a thread finishes using a pipe, it closes the pipe handles that are using the DosClose call. When no more open pipe handles are present, OS/2 automatically deletes the pipe.

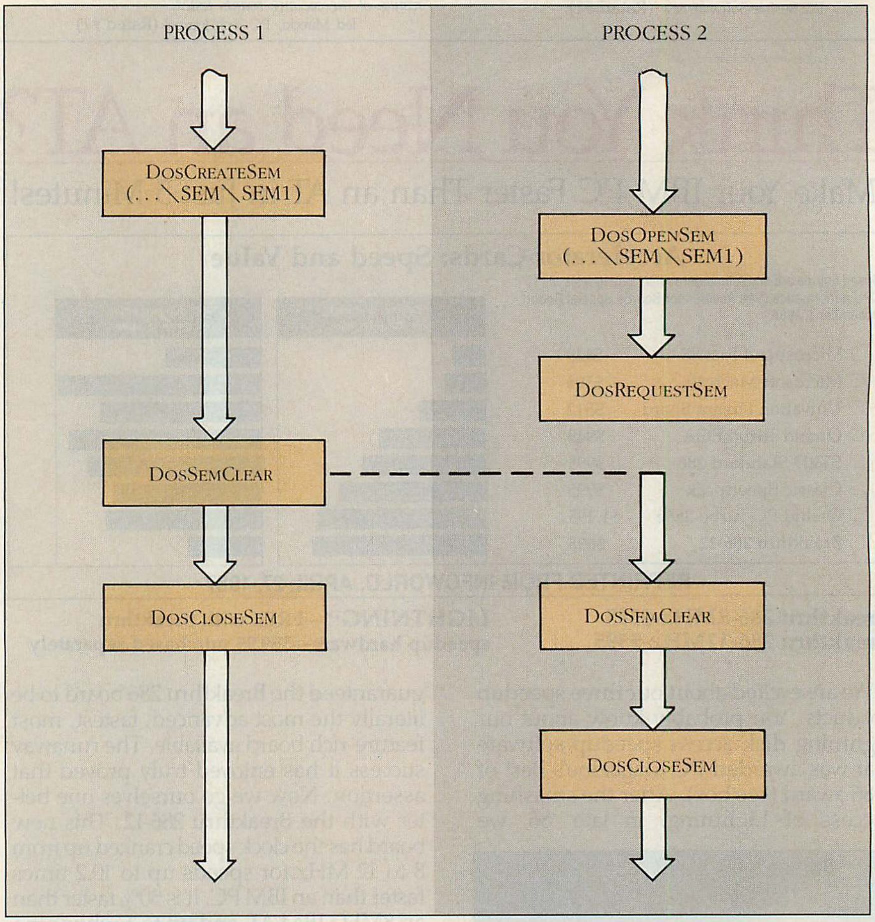
The typical use for pipes is for a parent process to create a pipe, use DosDupHandle to substitute the pipe handles for standard ones (such as **stdin** and **stdout**), and create child processes to use the handles. When a new process is created, it automatically inherits the handles of its parents, so when the threads in the new processes read from **stdin** and write to **stdout**, they will automatically communicate via the pipe set up by their parent process.

SHARED MEMORY

OS/2 provides several calls that enable threads in different processes to share the same data segment in memory. One mechanism for sharing segments involves using the DosAllocShrSeg and DosGetShrSeg functions. These two functions enable threads to access segments by name, much as threads access system semaphores. DosAllocShrSeg causes OS/2 to allocate a shared segment (up to 64KB in size) to the calling thread. The calling thread also specifies a name for this segment, which OS/2 stores in a SHAREMEM directory in memory. As with semaphores, the names must follow the rules for file names. DosAllocShrSeg returns a selector for the allocated segment.

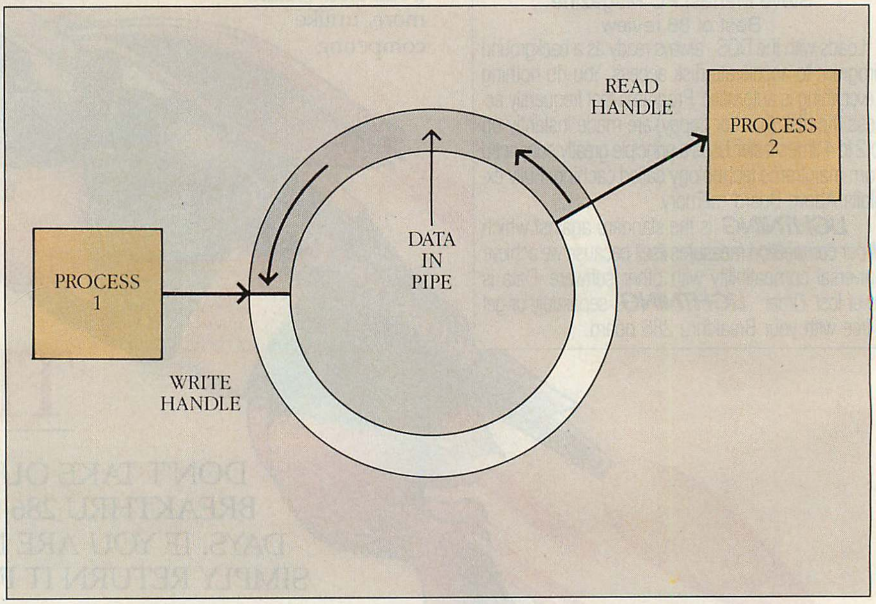
When a thread in another process needs to access the shared segment, it calls DosGetShrSeg, specifying the

FIGURE 4: ***Using a System Semaphore***



The first process that uses a system semaphore must create it. Subsequent users can open the semaphore using the agreed-upon name, in this case SEM1. After the last thread has closed the system semaphore, OS/2 deletes the semaphore.

FIGURE 5: ***Using Pipes***



Pipes are read from and written to using standard OS/2 file I/O calls; this often makes their use transparent to the processes involved. The pipe is maintained in a memory segment as a circular buffer. When the writing process fills the pipe, it is blocked until the reading process has read some of the data from the pipe.

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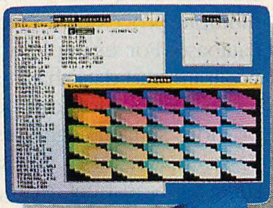

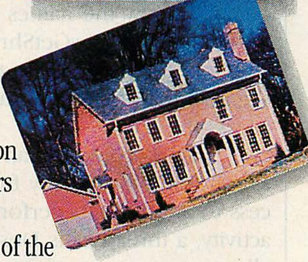

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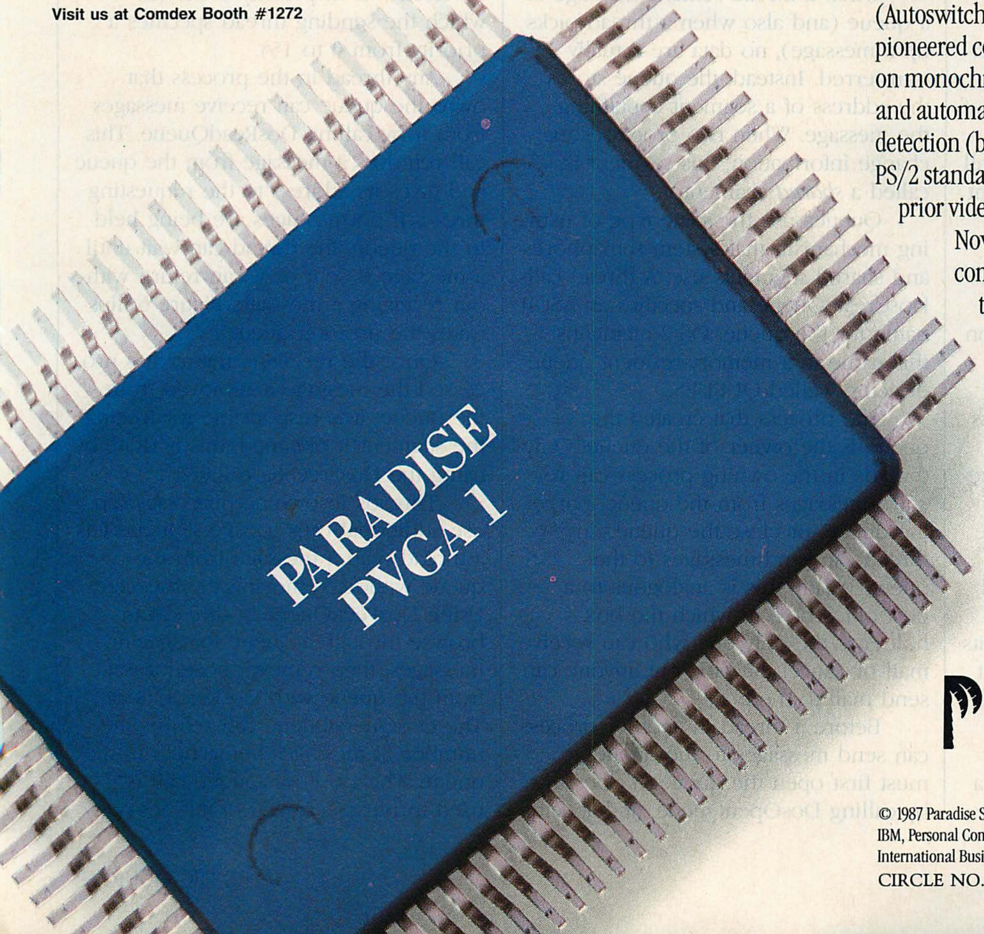

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name of the shared segment it wishes to access. This name must include the directory prefix \SHAREMEM\.

DosGetShrSeg returns a selector for the segment. This selector can differ from the one received by the thread that created the segment, so threads should not pass the shared segment selectors as data to other processes. However, all selectors returned by DosGetShrSeg for the same shared segment refer to the same memory.

For shared segments allocated with DosAllocShrSeg, OS/2 maintains an internal reference counter that is incremented when the segment is allocated and each time DosGetShrSeg is called. When a thread finishes with the segment and calls DosFreeSeg, the internal counter is decremented. When all threads have freed the segment (decrementing the count to zero), OS/2 frees the segment and removes its name from the SHAREMEM directory.

Using the DosAllocShrSeg and DosGetShrSeg calls is a good way for multiple processes to access a single database. For example, in a spreadsheet program, the data that make up the worksheet portion can be kept in one or more shared segments. All the processes that need to access that worksheet (spreadsheet, print, graph, and so on) will know the names of the segments and use DosGetShrSeg to get selectors for them. Once they have the segment selectors, they can directly access the data.

Shared segments can also be used to transfer data directly from one process to another. To perform this type of activity, a thread calls DosAllocSeg to allocate a segment of memory. This call does not place a name for the segment in the SHAREMEM directory, but a parameter in the call designates that the segment can be shared.

Once a thread has allocated a shared segment and placed information in that segment, it can share the segment with another process by calling DosGiveSeg and specifying the process ID of the process that will be sharing the segment. DosGiveSeg returns something called a recipient segment handle, which is simply a selector that the other process can use to access the segment. (The recipient's selector will be different because the segments accessible to each process are listed in its LDT, and each process uses a different LDT. Therefore, each process needs a selector that refers to its own LDT.)

After calling DosGiveSeg, the thread has a selector that a thread in a different process can use to access the shared segment, but the thread still needs to let the other process know what that selector is. To pass the selector of a shared segment to a thread in another process, another object, called a queue, is used.

QUEUES

A queue is simply a place that one thread can drop off a message to another thread, much like a post office box is a place where people can send messages to one another. Threads do not need to synchronize using queues, as they would when using pipes. Instead, one thread simply sends a message to the queue for safe keeping and another thread requests the message later. Queues are useful for transferring shared memory between processes, but threads in the same process can also use queues to exchange information.

OS/2 queues use the same type of naming mechanism that is used by both the system semaphores and the shared segments.

When a thread sends a message to a queue (and also when a thread picks up a message), no data are actually transferred. Instead, the queue stores the address of a segment containing the message. When two processes exchange information, this segment is called a *shared* segment.

Queues use the same type of naming mechanism that system semaphores and shared segments use. A thread calls DosCreateQueue and specifies an ASCII name for the queue. OS/2 maintains this name in a memory-resident queue directory called QUEUES.

The process that created the queue is the owner of the queue. Only threads in the owning process can receive messages from the queue, purge the queue, or close the queue. Any thread can send messages to the queue. Again, this is analogous to a post office box, in which the box holder is the only one who can receive mail or cancel the box, but anyone can send mail to the box.

Before a thread in another process can send messages to the queue, it must first open the queue. It does this by calling DosOpenQueue, and specifying the ASCII name of the queue. The name must include the directory name \QUEUES\. DosOpenQueue, in response, returns a handle that the thread can use when invoking other queue calls and the ID of the process that owns the queue. Having this ID is important because, in order to send a message to another process, the thread must prepare a shared segment to contain the message. Before it can send the shared segment to the queue, it must also call DosGiveSeg to obtain a selector that the other process can use. DosGiveSeg requires as input the process ID of the process that will be sharing the segment.

Once a thread opens a queue, it can send a message to it by calling DosWriteQueue and specifying the address of the message. As was mentioned earlier, this address must be one that is accessible to the receiving process. Therefore, a thread that is in a different process than the queue must allocate shared memory and call DosGiveSeg to obtain a valid address before sending to the queue.

Multiple messages can be sent to a queue; the order in which the messages are stored in the queue depends on a parameter specified when the queue was created. Messages can be maintained in FIFO order (the first one sent is the first one received), in LIFO order (the last one sent is the first one received), or in priority order (in which the sending thread specifies a priority from 0 to 15).

Any thread in the process that owns the queue can receive messages from it by calling DosReadQueue. This call removes a message from the queue and gives its address to the requesting thread. If no messages are being held in the queue, the thread can wait until a message is sent or it can return without receiving a message. Figure 6 illustrates the use of a queue.

Once the receiving thread has processed the message it removed from the queue, it is responsible for freeing the segment it obtained; this is done by using the DosFreeSeg call.

Threads in owning processes can use additional calls. DosPeekQueue lets a thread read a message from the queue without removing the message. Using DosPeekQueue, a thread can browse through a queue for specific messages, then remove those messages from the queue with DosReadQueue. The DosQueryQueue call returns the number of messages being held in the queue. The DosPurgeQueue call is used to purge a queue of all messages.

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The DosCloseQueue call is used to close a queue and remove its name from the QUEUES directory.

SIGNALS

Signals are another mechanism for interprocess communication. They are primarily used to handle external events, such as the operator pressing Ctrl-C or Ctrl-Break. However, signals can also be used to enable processes to communicate with each other. Using signals is analogous to using software interrupts under DOS.

The OS/2 signal facility enables a process to designate on-condition handlers that will gain control whenever a particular signal occurs. Signals occur when the following events take place: Ctrl-C is pressed, Ctrl-Break is pressed, a process is terminated by calling DosKill, or a general-purpose signal is sent by another process.

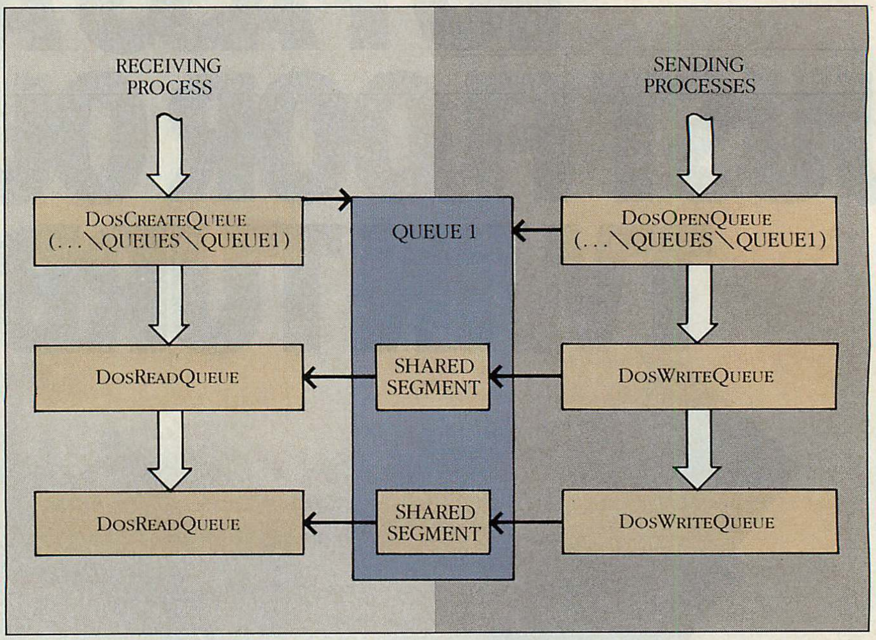
A thread sets up a signal handler by calling DosSetSigHandler and specifying the address of the routine that will handle the signal and the type of signal it will handle. The signal types are the specific ones mentioned earlier and three general-purpose signals (process flags *A*, *B*, and *C*). The specific signals enable an application to perform special processing when one of the interrupt keys is pressed (Ctrl-C or Ctrl-Break) or to perform clean-up operations just before the process is deleted. The general-purpose signals enable signals to be sent via software rather than by external events.

When a signal occurs while a process is active, thread one of that process (the first one started when the process was created) is diverted in a forced call to the signal handler. Because the signals often represent time-critical events, if thread one is processing a call that will not return quickly, the call will be aborted and return an error code. Slow calls are normally device I/O calls. File system calls (opening and closing, or reading and writing files) are not aborted.

Because signals are always serviced by thread one, applications that use signals may want to reserve this thread for signal processing, perhaps blocking on a RAM semaphore, and create other threads for program execution.

When a signal handler receives control, the stack is updated to contain the following information: the far return address of the thread that was interrupted, the number of the signal that just occurred, and the value of an *argument* passed to the signal handler. The argument is a word that enables the threads that cause general-purpose signals to pass small amounts of data to the signal handler. External signals (Ctrl-C, Ctrl-Break, or DosKill) do not pass any meaningful information in this particular argument.

FIGURE 6: *Using Queues*



Queues are particularly good for large messages because data are not copied between processes. The queue is created by a process that wants to receive messages. One or more processes can open the queue by its agreed-upon name and send messages. Messages consist of a 16-bit number (its meaning is application-defined) and a pointer to a shared data segment allocated by the sender.

The signal handler can then perform any operations it needs in response to the signal. For example, in response to a Ctrl-C, a signal handler could close open files, free all allocated memory, delete threads, and perform any other clean-up operations before being terminated. When it finishes, the signal handler can execute an intersegment return instruction to resume execution at the point at which it was interrupted. Or, it can manually set the stack frame to a known state and jump to a known location.

Threads can send signals to signal handlers by calling DosFlagProcess. This sends one of the signals (process flag *A*, *B*, or *C*) to the process indicated in the call. If there is no signal handler set up for that signal in the specified process, the signal is ignored.

In addition, threads can call DosHoldSignal to disable signal processing during critical periods of operation. This is analogous to disabling interrupts under DOS. For example, if a thread is performing a time-critical operation, updating a sensitive area of data, or performing some other operation that should not be interrupted, it does not want to be interrupted by having the operator press Ctrl-Break. It can use DosHoldSignal to turn off signal processing while performing the critical operations. After it finishes, it can call DosHoldSignal to turn signal processing back on. Turning signal processing back on is analogous to enabling the interrupts.

When signal processing is turned off, occurring signals are recognized but not accepted until it is turned on again. Because signals often represent critical events that should be handled quickly, signals should be treated like hardware interrupts and turned off only for short periods.

OS/2 provides a full range of functions for multitasking operation and several mechanisms for communication between multitasking elements. It remains to be seen how large applications will take advantage of these features. All the tools are in place, however, to provide multitasking applications that are as sophisticated as any in the microcomputer world.

Steven Armbrust is a freelance technical writer, and Ted Forgeron works as a program manager for Intel Corporation. Together, they are the authors of the Programmer's Reference Manual for IBM Personal Computers *(Dow-Jones, Irwin, 1986).*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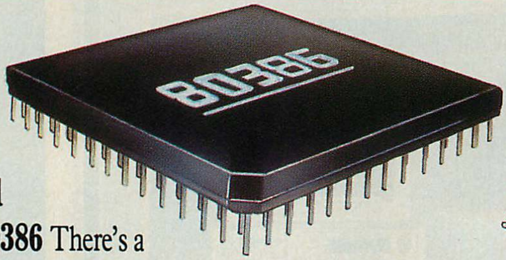

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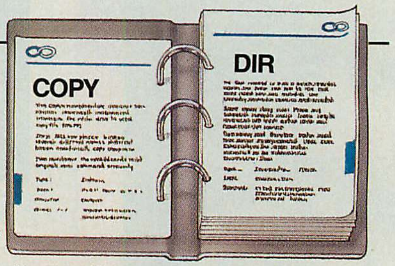

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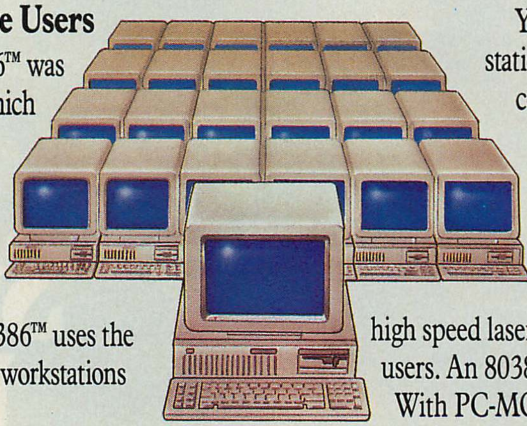

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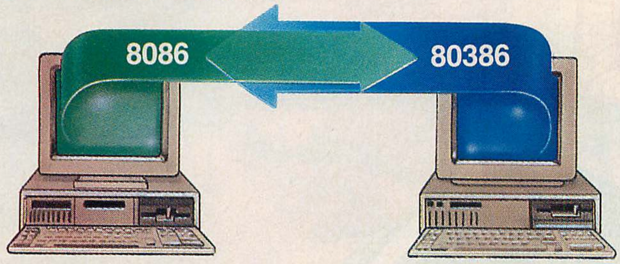

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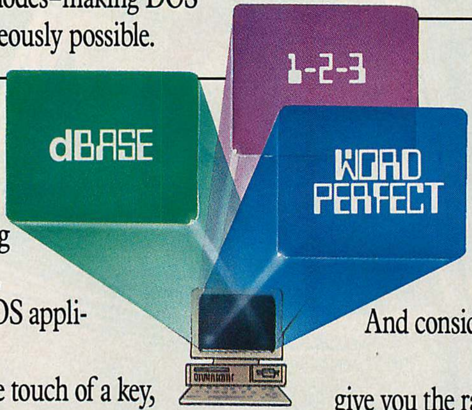

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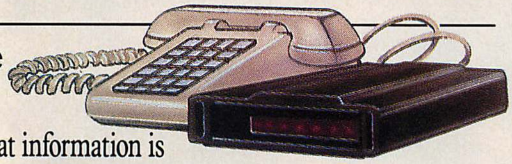

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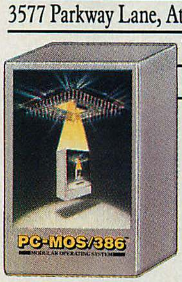

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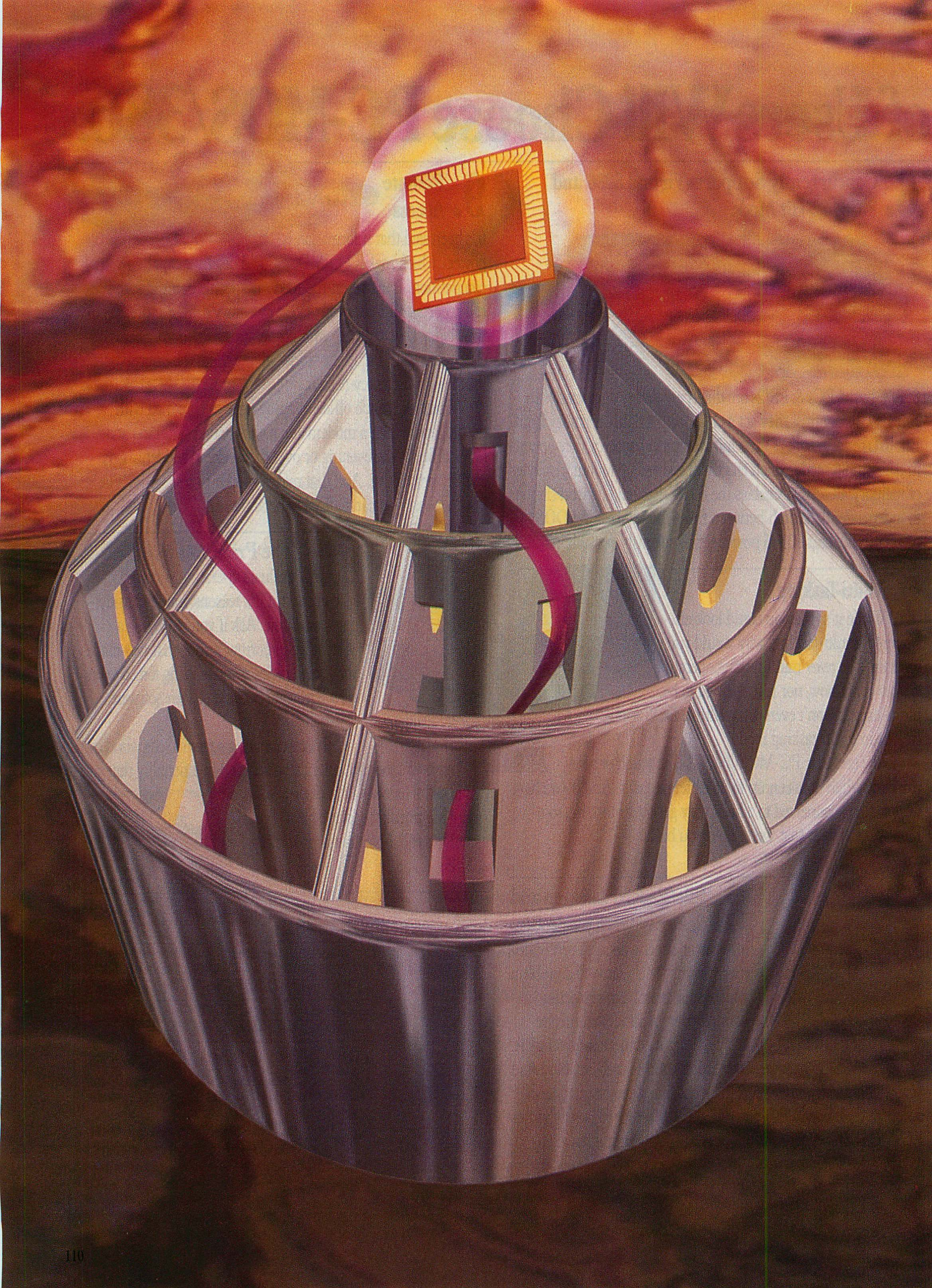

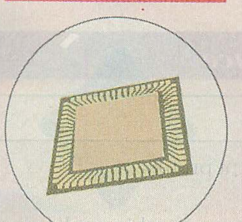

One of OS/2's strong selling points is its unique API that can be accessed from high-level languages and expanded gracefully.

The Flexible Interface

DAVID A. SCHMITT

When the applications programmers finally tear open the Operating System/2 (OS/2) box, they will discover an operating system that affords them greater flexibility than they previously enjoyed under DOS, thanks to the OS/2's greatly improved application program interface (API).

Broadly speaking, an API includes all the ways in which an application can interface with the operating system. More specifically, the API consists of the host operating-system services available to a program and the techniques used to call them. Both DOS and OS/2 APIs define protocols to receive control from the operating system when the application begins; request operating-system services such as I/O; return control to the operating system when the application finishes; and connect special I/O drivers to the operating system.

How these services are accessed draws the distinction between the DOS and the OS/2 APIs. DOS, like most other operating systems, defines an API that is convenient only for assembly language programmers; whereas the OS/2 API is, for the most part, accessible from high-level languages, such as C and Pascal. The service functions have names instead of numbers and are accessed with call instructions instead of interrupts. They can be called from many languages that support a standard calling sequence and linking with externally compiled modules. Therefore applications programmers easily can bypass the standard compiler libraries and call OS/2 service functions directly in order to obtain more efficient performance or to handle special processing requirements.

Because OS/2 services are not strictly confined to the operating-system kernel but are implemented through dynamic-link libraries, it is easy to add to the operating system such functions as network managers, graphics interfaces, communications, and data managers. These additions, which can be integrated into the operating system and accessed through the standard API, need not originate solely from either Microsoft or IBM.

When DOS turns control over to an application program, it sets the registers and the program-segment prefix (PSP), as shown in table 1. The application usually must save some of this information and put different values into the segment registers. For example, the application might repoint the DS register from the PSP to the program's default data segment and move the residual command line into the same data segment to make processing more convenient. The applications programmer must use assembly language for this initialization because most of the high-level languages do not provide easy access to machine registers.

In DOS, the application program also must drop back to assembly language to terminate; it loads a return code into the AL register, 4CH into the AH register, and executes DOS interrupt 21H. DOS also allows applications to terminate and stay resident (TSR), which is a way of keeping the application program in memory so that it may attempt some type of multitasking.

An OS/2 application also requires an assembly language start-up interface because its entry information is passed in registers (see table 2). This is surprising in light of the high-level API to the OS/2 service functions. If the start-up data passed on the stack instead of in registers, the application's start-up routine could use a high-level language syntax to access the data as if they were arguments passed to a function.

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TABLE 1: ***DOS Program Entry Interface***

LOCATION	CONTENTS
DS	Segment address of program segment prefix
ES	Same as DS
SS	Segment address of default stack segment within application
SP	Offset to top of default stack
BX:CX	32-bit length of executable file, excluding .EXE header
PSP + 2CH	Segment address of environment area containing this application's copy of environment strings followed by name of executable file loaded for application
PSP + 5CH	Partial unopened FCB containing drive number, file name, and extension from first parameter following command verb
PSP + 6CH	As above, for second parameter
PSP + 80H	128-byte area containing residual command line, preceded by a length byte

When an application program gains control under DOS, it needs an assembly language start-up routine because the information is passed in the registers.

TABLE 2: ***OS/2 Program Entry Interface***

REGISTER	CONTENTS
DS	Segment selector for default data segment or 0 if no such segment
ES	Value of 0
SS	Segment selector for default stack segment
SP	Offset to top of default stack
AX	Segment selector for environment segment containing environment strings, application file name, command verb, and residual command line
BX	Offset to command verb in environment segment
CX	Length of default data segment with 0 indicating 64KB
DX	Stack size
SI	Heap size
DI	Module handle for application executable
BP	Value of 0 normally pushed onto stack to indicate end of stack frame chain

Under OS/2, a program gets more information from the operating system at start up, but the information is still accessible only with assembly language.

Actually, this is not a serious problem because compiler packages always include an appropriate start-up routine, and most compiler vendors are now supplying start-up source code with which the user can customize the code for special applications. Still, the assembly language start-up seems at odds with the rest of the OS/2 API.

OS/2 eliminates the PSP, because the start-up data previously provided in the PSP now are passed in the registers and the environment area. However, the new operating system has two additional blocks of process information; the application obtains its addresses by calling DosGetInfoSeg. These blocks contain the process and thread identifiers, thread priorities, screen group, and so on, although few applications need this information. *Processes*, *threads*, and *screen* groups are classes of tasks that can run concurrently; they are more fully described later in this article.

An OS/2 application can terminate, without recourse to assembly language, simply by calling the DosExit function and passing a return code as a parameter. While DOS allows only an 8-bit code, OS/2 allows 16 bits. When it terminates, the application also is able to specify the immediate termination of its threads or associated tasks.

In OS/2, the information an application receives from the command line includes one additional item not available in DOS, the *command verb*. For example, in the OS/2 user command

```
link myprog /m;
```

the command verb is **link** and the residual command line is **myprog /m;**. Although DOS provides no way to obtain the command verb itself, the programmer can obtain an executable file name, which normally has the verb as its root. In this example, the executable file might be **link.exe**.

Like the entry and exit sequences of DOS applications, the interface to DOS service functions was designed strictly for use by assembly language programs. After three major versions of DOS, this portion of the API has evolved into about 100 services that are accessed by the following protocol:

- The application passes data (both values and addresses) in machine registers, and DOS returns these data in the same fashion.
- The application passes control to the system through a software interrupt. The most common DOS services use interrupt 21H, but the DOS API now includes many other interrupts, such as those used to access the BIOS.
- DOS API routines, in general, do not preserve the register contents.
- The API routines usually indicate errors by setting the carry flag (CF) when they return to the application.

This protocol is illustrated by a code fragment that reads a block of data from a file (figure 1). It is assumed that the file was opened before by another DOS function call and that the buffer is in the default data segment to which the DS register points.

The DOS API is efficient but has serious drawbacks. Although it is well-suited to assembly language, it cannot be used from high-level languages because they generally do not allow direct manipulation of the registers or direct execution of interrupt instructions. Thus, compiler libraries need many "glue functions" that pick up parameters from where the calling sequence put them (usually on the stack), place them into registers, and issue software interrupts.

DOS also includes many exceptions to the four-point protocol described above. For example, register usage varies from one function to the other, and some API functions do not use the CF to indicate errors. Finally, because DOS resides in the same memory space as its application programs, many programmers have discovered how to access "secret" data areas and functions within DOS, which they treat as part of the API. These procedures can cause compatibility problems when DOS is updated.

THE GRAND DESIGN

The OS/2 designers sought to correct these problems by providing an API with functions that can be called di-

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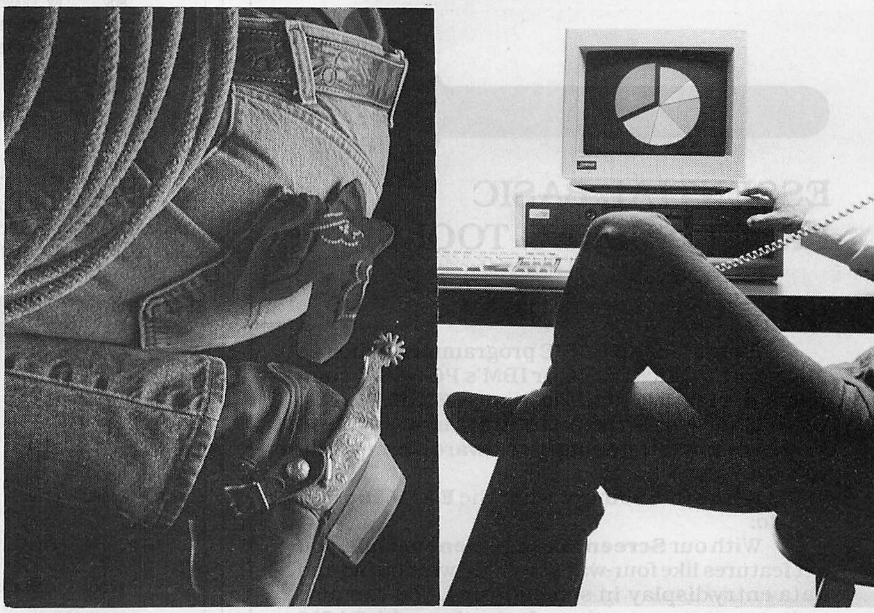

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FIGURE 1: *DOS Example*

```
; In the Data Segment:

FHANDLE DW      ?               ;File handle
NBYTES  DW      ?               ;No. of bytes to read
BUFFER  LABEL   BYTE            ;Buffer to receive data

; In the Code Segment:

        MOV     BX,FHANDLE      ;Load file handle
        MOV     CX,NBYTES       ;Load read count
        LEA     DX,BUFFER       ;Load buffer offset (Seg in DS)
        MOV     AH,3FH          ;DOS file read function
        INT     21H             ;Call DOS
        JC      READ_ERROR      ;Handle any errors
                                ;Continue if read OK
```

A call to the file-reading function of DOS illustrates why this API can be used only from assembly language: values are passed in registers, and entry is via a software interrupt.

FIGURE 2: *Assembly Language Example*

```
; In the Data Segment:

FHANDLE DW      ?               ;File handle
NBYTES  DW      ?               ;No. of bytes to read
ACTUAL  DW      ?               ;No. of bytes actually read
BUFFER  LABEL   BYTE            ;Buffer to receive data

; In the Code Segment:

        EXTRN   DOSREAD:FAR
                                ;Push parameters for call:
        PUSH    FHANDLE         ;  file handle,
        PUSH    DS              ;  far address of buffer,
        LEA     AX,BUFFER
        PUSH    AX
        PUSH    NBYTES          ;  byte count,
        PUSH    DS              ;  far address for returned count.
        LEA     AX,ACTUAL
        PUSH    AX
        CALL    DOSREAD         ;Call DOS function
        OR      AX,AX           ;Test value returned in AX
        JNZ     READ_ERROR      ;Handle any errors
                                ;Continue if read OK
```

The equivalent function call in OS/2 shows features of the new API: the functions are called by name, with parameters passed on the stack instead of in machine registers.

FIGURE 3: *C Language Example*

```
/* Declarations */
extern far pascal DOSREAD(short, char far *,
                          short, short far *);

int retcode, handle, length;
short actual;
char *buffer;

/* Code */

retcode = DOSREAD( handle, (char far *)buffer,
              length, (short far *)(&actual) );
if(retcode)
  /* Error occurred: process it */
else
  /* Read OK: process the input */
```

Because the function-calling protocol of the OS/2 API is the same as those found in many compilers, system services may be called directly from high-level languages.

rectly from languages such as C and Pascal. Because these languages impose fairly strict and consistent function-calling protocols, and high-level functions are easily documented, this type of API is more accessible to the average programmer. Further, the risk of obscure errors caused by incorrect API calls is greatly reduced because the functions have mnemonic names instead of cryptic numbers, and the compiler can check for valid argument types.

Of course, a high-level API does not preclude assembly language programming, because a programmer can hand-code in assembly language any code sequence generated by a compiler. In assembly language terms, the protocol for the OS/2 API is as follows:

- The application program pushes all parameters onto its stack.
- The integer (16-bit) and the long-integer (32-bit) input parameters to the function are passed onto the stack by the values themselves.
- Character and parameter values returned by the API function are passed by address—the application pushes the parameter's full 32-bit address.
- Control transfers to the API function by means of a far call.
- The API function preserves all registers except for AX.
- As it returns, the API function removes all parameters from the user's stack, then passes back a return code in AX. This code is zero for success or nonzero for an error.

Many compilers use this protocol for calling functions. In most languages, invoking a function pushes the function's parameters onto the stack, and an integer value returned by the function usually passes back into AX.

The OS/2 API is illustrated by examples in assembly language and C in figures 2 and 3, respectively. In both cases, the code fragments perform the same function as the code in figure 1—they read a block of data from a previously opened file into a buffer in the default-data segment. The OS/2 DosRead function performs the same operation as DOS interrupt 21H, function 3FH. As with any function that is accessible from a high-level language, accessing OS/2 through assembly language is more complicated, more tedious, and probably more error prone.

Comparing the assembly code sequences in figures 1 and 2, it is apparent that the OS/2 API is less efficient than its predecessor. It takes more instructions and machine cycles to push arguments onto the stack than to place them in registers; in addition, the far

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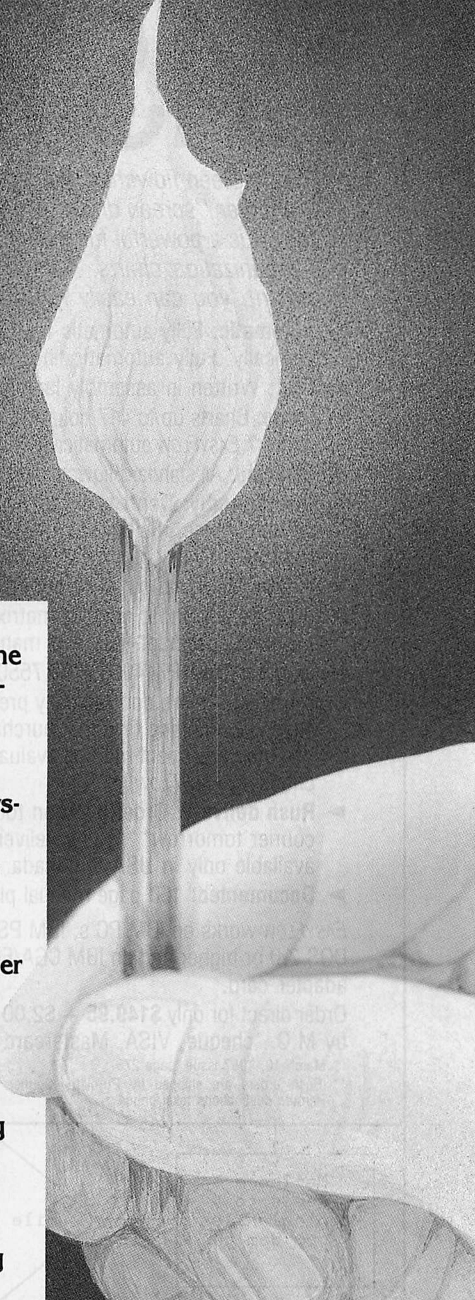

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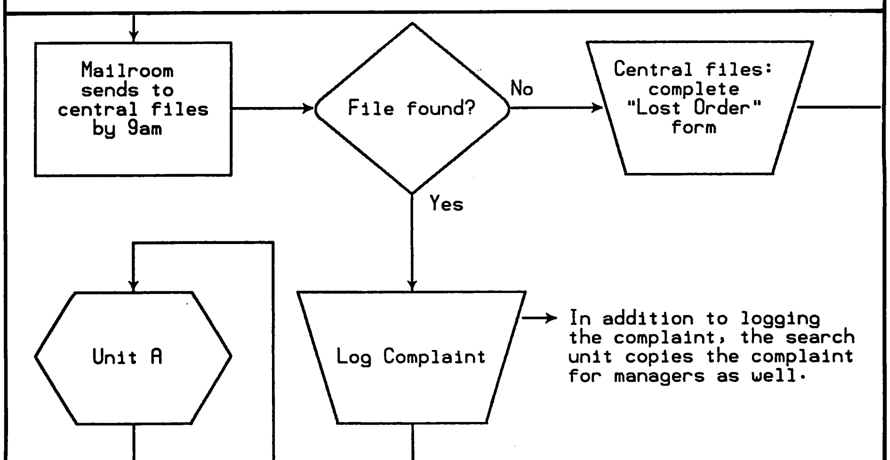

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call is larger and slightly slower than the interrupt instruction. This is undoubtedly a reasonable trade-off because, in many cases, OS/2 API's direct accessibility from a high-level language obviates the use of glue functions that, under DOS, simply pop the arguments right back off the stack and issue the appropriate software interrupt.

For example, the standard C **read** function, included in many compiler libraries, reads a block of data from a file. Under DOS, if this function were written in assembly language, it would incorporate a code sequence similar to the one in figure 1. Reading a file involves two calling sequences: one conforming to the C protocol to call **read** and the other to the DOS API to call interrupt 21H. Under OS/2, the programmer can write the **read** function in either assembly language or C, but in either case the operating system is called, using the longer calling sequence shown in figure 2. Therefore it would appear that a program to call a standard library function is less efficient under OS/2, because it uses two long calling sequences instead of one short sequence and one long sequence.

However, the program does not need to call **read**—it can simply call the DosRead function directly. This is more efficient than DOS because it involves only one calling sequence. In effect, the program can bypass the glue function to call the operating system directly. The trade-off for this case is that the program becomes tied to OS/2 and loses the portability that is a hallmark of C language.

Figure 3 illustrates several other requirements of writing OS/2 calls in C. First, the programmer must declare the API functions using the **far** and **pascal** key words. **Far** instructs the compiler to use a far call to access the function, regardless of the memory model in use; **pascal** indicates that the function does not conform to standard C language calling conventions and causes the compiler to generate the following function protocol:

- Arguments are pushed onto the stack in right-to-left order as written (the standard C sequence pushes arguments left to right).
- No code is generated following the call to remove arguments from the stack; it is assumed that the function performs this task before returning.
- The name of the function is converted to uppercase; it is not preceded with an underscore.

Second, all pointer arguments passed to OS/2 functions must be 32-bit

TABLE 3: *OS/2 Video Functions*

FAMILY	INT 10H EQUIV.	NAME	DESCRIPTION
		VioDeRegister	Deregister video subsystem
		VioEndPopUp	Deallocate pop-up display screen
		VioGetANSI	Get ANSI status
F		VioGetBuf	Get logical video buffer
		VioGetConfig	Get video configuration
		VioGetCp	Get video code page ID
F	03H	VioGetCurPos	Get cursor position
F		VioGetCurType	Get cursor type
		VioGetFont	Get font table address
F	0FH	VioGetMode	Get display mode
F		VioGetPhysBuf	Get physical display buffer
		VioGetState	Get video state
		VioModeUndo	Cancel mode wait
		VioModeWait	Wait for mode change
		VioPopUp	Allocate pop-up display screen
		VioPrtSc	Print screen
		VioPrtScToggle	Print screen key operation trap
F	08H	VioReadCellStr	Read cell string
F		VioReadCharStr	Read character string
		VioRegister	Register video subsystem
		VioSavRedrawUndo	Cancel save-redraw wait
		VioSavRedrawWait	Wait for save-redraw
		VioScrLock	Lock the screen
F	07H	VioScrollDn	Scroll down
F		VioScrollLf	Scroll left
F		VioScrollRt	Scroll right
F	06H	VioScrollUp	Scroll up
		VioScrUnLock	Unlock the screen
		VioSetANSI	Set ANSI mode on or off
		VioSetCp	Set video code page ID
F	02H	VioSetCurPos	Set cursor position
F	01H	VioSetCurType	Set cursor type
		VioSetFont	Set font
F	00H	VioSetMode	Set display mode
	0BH	VioSetState	Set video state
F		VioShowBuf	Display logical buffer
F	09H	VioWrtCellStr	Write cell string
F	0AH	VioWrtCharStr	Wrtie character string
F		VioWrtCharStrAttr	Write character string with attribute
F		VioWrtNAttr	Write N attributes
F		VioWrtNCell	Write N cells
F		VioWrtNChar	Write N characters
F	0EH	VioWrtTTY	Write a TTY string

F = Full family-mode support

Besides providing the equivalent of DOS BIOS-level video output functions, OS/2 also allows direct access to either the logical or the physical video buffers.

far pointers. To ensure the proper pointer format under all memory models, each argument should be converted by a *cast*, as illustrated by the code **(char far *) buffer** and **(short far *) (&actual)** in figure 3.

Usually, the program would not explicitly declare the API functions, but would include from the OS/2 Programmer Toolkit the appropriate definition files, often called *header* or *include* files. For C programmers, the standard API functions are defined in two header files named **subcalls.h** and **doscalls.h**. The former defines the keyboard, video, and mouse functions that compose the user-interface subsystem; the latter contains definitions for all remaining functions. The files also define complex API data structures.

The early OS/2 documentation is somewhat unclear about how the user should actually write the API function names. The OS/2 *Technical Reference Manual* often shows them in mixed case, such as DosRead, but then warns the user to code them in full uppercase, such as DOSREAD. In the preliminary release, the function declarations in the header files and the module names in the libraries contain only uppercase names. If a programmer uses mixed case in a program with a case-sensitive compiler, then he must instruct either the compiler or the linker to fold all such names to uppercase. For some C compilers, **pascal** in the function declarations performs this task, at least for the module names passed to the linker.

The API function libraries also contain complete function names, some of them quite long. Compilers, assemblers, and linkers often have options that allow the user to truncate external names to eight characters or fewer; sometimes these options are in effect by default. The programmer cannot use these options when a program includes OS/2 API calls; if the options are used, the linker will be unable to resolve the function references correctly.

Doscalls.lib is the link-time library used to resolve calls to external API functions. Unlike normal libraries that supply actual program code for modules called, this library supplies *definition records* for dynamically linked modules. These records contain information that the linker places into the .EXE file for use at load time. When the file is loaded, this information allows OS/2 to find the file containing the actual code and load the required modules. If the library is not already in memory, OS/2 will load it. In either case, it then performs a relocation process by inserting the actual addresses of the modules called. Several concurrent processes needing the same modules can share one copy of each dynamic-link library.

IN THE FAMILY MODE

Family mode is a novel feature of OS/2 that allows the user to construct an application that will run under DOS 3.x, OS/2 real mode, or OS/2 protected mode; however, one might ask, if an application can run in protected mode, why should it run in OS/2 real mode? The rules for constructing such an application are as follows:

- The program can freely call those OS/2 API functions designated for use in family mode.

- The program cannot call nonfamily OS/2 API functions unless it first verifies that it is in protected mode.
- The program cannot use any DOS API services, such as generating software interrupts, unless it first verifies that it is running in (DOS 3.x or OS/2) real mode.
- Programs that directly manipulate the segment portions of 32-bit addresses must incorporate code that reflects both real-mode and protected-mode addressing and must conditionally execute one or the other, depending on the runtime mode.

OS/2 includes several features to support family-mode applications. It has API functions to distinguish between DOS 3.x and OS/2 and between real and protected modes. A special library file called **api.lib** contains DOS versions of the family-mode subset of OS/2 functions. The **bind** utility converts a protected-mode .EXE file into a family-mode .EXE by inserting the DOS versions of the API functions and a *stub loader*, which loads these functions into memory (and performs appropriate relocation of call addresses) if the program initiates from DOS or OS/2's compatibility mode. In protected mode, the stub loader is not executed, and the real-mode functions never load. On disk, the executable family mode is about 30KB larger than the straight protected-mode (unbound) file.

OS/2 API services. The more than 200 OS/2 API service functions are listed in tables 3 through 10 and are grouped according to function: video, keyboard, mouse, file I/O, memory management, task management, interprocess communication, and miscellaneous.

In the tables, the FAMILY column indicates the extent to which the function can be used in family-mode programs. F in this column indicates that the function is fully supported for use in family-mode applications in both real and protected modes; whereas R indicates that the function can be used in real mode with certain restrictions, which are usually on the use of some of the function's capabilities or on the values of parameters.

The DOS EQUIVALENT column shows the DOS API services that are roughly equivalent to the OS/2 API functions. In most cases, the equivalence is a function of DOS interrupt 21H, but the tables also indicate the cases in which other interrupts provide particular services.

Table 11 presents the equivalence information for interrupt 21H only in DOS function-code order. Nearly all

TABLE 4: *OS/2 Keyboard Functions*

FAMILY	DOS EQUIVALENT	NAME	DESCRIPTION
F	INT 16H,00H	KbdCharIn	Read character and scan code
		KbdClose	Close logical keyboard
		KbdDeRegister	Deregister keyboard subsystem
		KbdFreeFocus	Free keyboard focus
F		KbdFlushBuffer	Flush keystroke buffer
		KbdGetFocus	Get keyboard focus
F	INT 16H,00H	KbdGetStatus	Get keyboard status
		KbdGetCP	Get keyboard code page ID
		KbdOpen	Open logical keyboard
R	INT 16H,00H	KbdPeek	Peek at character and scan code
		KbdRegister	Register keyboard subsystem
		KbdSetCP	Set keyboard code page ID
		KbdSetCustXt	Set custom translate table
		KbdSetFgnd	Set foreground keyboard priority
		KbdSetStatus	Set keyboard status
		KbdShellInit	Initialize shell
F	INT 21H,0AH	KbdStringIn	Read character string
		KbdSynch	Synchronize keyboard access
		KbdXlate	Translate scan code

F = Full family-mode support
R = Restricted family-mode support

Control over the OS/2 keyboard is much more complete than in DOS and extends to scan-code translation and foreign character sets.

TABLE 5: *OS/2 Mouse Functions*

INT 33H EQUIV.	NAME	DESCRIPTION
	MouClose	Close mouse device
	MouDeRegister	Deregister a mouse subsystem
01H	MouDrawPtr	Draw a pointer
	MouFlushQue	Flush mouse event queue
	MouGetDevStatus	Get mouse device status flags
	MouGetEventMask	Get mouse event mask
	MouGetHotKey	Get mouse hot-key definition
	MouGetNumButtons	Get number of mouse buttons
	MouGetNumMickeys	Get number of mickeys per centimeter
	MouGetNumQueEl	Get number of mouse event queue elements
03H	MouGetPtrPos	Get mouse pointer position
	MouGetPtrShape	Get mouse pointer shape
	MouGetScaleFact	Get mouse scaling factors
	MouInitReal	Initialize real-mode mouse driver
00H	MouOpen	Open mouse device
05H,06H	MouReadEventQue	Read mouse event queue
	MouRegister	Register a mouse subsystem
02H	MouRemovePtr	Remove mouse pointer from a screen area
	MouSetDevStatus	Set mouse device status flags
0CH	MouSetEventMask	Set mouse event mask
	MouSetHotKey	Set mouse hot-key definition
04H	MouSetPtrPos	Set mouse pointer position
09H,0AH	MouSetPtrShape	Set mouse pointer shape
	MouSetScaleFact	Set mouse scaling factors
	MouShellInit	Initialize shell linkage
	MouSynch	Synchronize mouse subsystem

Mouse functions can be used only in protected mode, not by family-mode programs. The interrupt 33H functions are only approximately equivalent.

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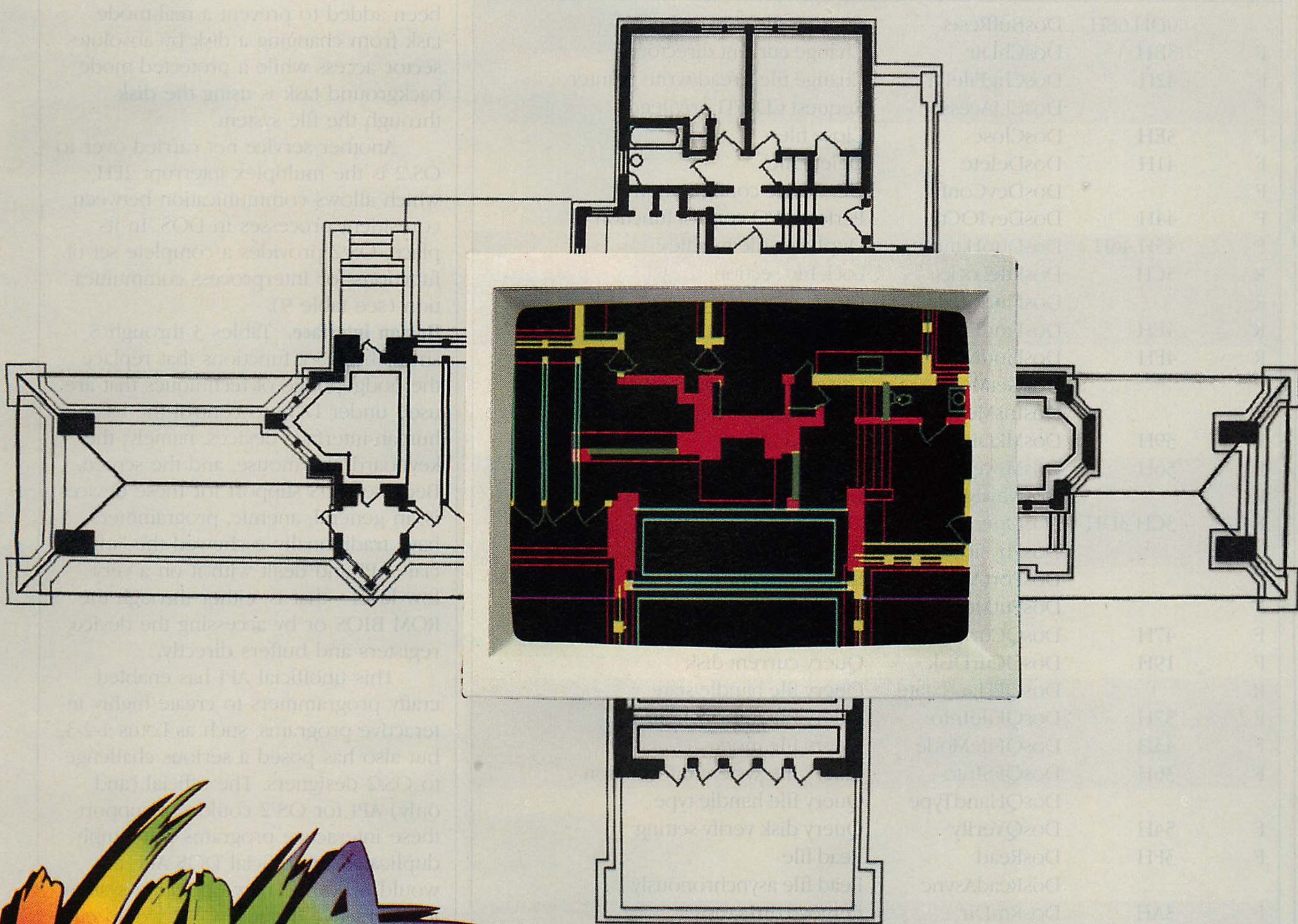

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TABLE 6: *OS/2 File I/O Functions*

FAMILY	INT 21H EQUIV.	NAME	DESCRIPTION
	0DH,68H	DosBufReset	Commit file's cache buffers
F	3BH	DosChDir	Change current directory
F	42H	DosChgFilePtr	Change file's read/write pointer
F		DosCLIAcess	Request CLI/STI privilege
F	3EH	DosClose	Close file
F	41H	DosDelete	Delete file
F		DosDevConfig	Get device configuration
F	44H	DosDevIOCtl	Perform I/O control function
F	45H,46H	DosDupHandle	Duplicate file handle
R	5CH	DosFileLocks	Lock file section
R		DosFindClose	Close directory handle
R	4EH	DosFindFirst	Find first matching file
R	4FH	DosFindNext	Find next matching file
F		DosGetMessage	Get system message with variable text
F		DosInsMessage	Insert variable information into message
F	39H	DosMkDir	Create directory
F	56H	DosMove	Move file
F		DosNewSize	Change file size
R	3CH,3DH	DosOpen	Open file
		DosPhysicalDisk	Request disk partition information
F		DosPortAccess	Request I/O port access
F		DosPutMessage	Put message to specified file handle
F	47H	DosQCurDir	Query current directory
F	19H	DosQCurDisk	Query current disk
R		DosQFHandState	Query file handle state
F	57H	DosQFileInfo	Query file information
F	43H	DosQFileMode	Query file mode
F	36H	DosQFSInfo	Query file system information
		DosQHandType	Query file handle type
F	54H	DosQVerify	Query disk verify setting
F	3FH	DosRead	Read file
		DosReadAsync	Read file asynchronously
F	3AH	DosRmDir	Remove directory
F		DosSearchPath	Search path for file name
F	0EH	DosSelectDisk	Select default disk
R		DosSetFHAndState	Set file handle state
F	57H	DosSetFileInfo	Set file information
F	43H	DosSetFileMode	Set file mode
F		DosSetFsInfo	Set file system information
	67H	DosSetMaxFH	Set maximum file handles
F	2EH	DosSetVerify	Set or reset verify switch
F	40H	DosWrite	Write file
		DosWriteAsync	Write file asynchronously

F = Full family-mode support *R = Restricted family-mode support*

Reflecting the similarity of the DOS and OS/2 file systems, this group of functions has the greatest percentage of equivalents in both operating systems.

DOS interrupt 21H services have OS/2 API equivalents, with three major exceptions: CP/M-like printer and serial-port services (functions 3, 4, and 5), because the OS/2 file system provides much better support for these devices by means of file handles; CP/M-like I/O services using file-control blocks (functions 0FH through 17H plus several others), because this approach has become somewhat obsolete since DOS 2.0; and networking services (codes 5EH and 5FH), because these are provided by the OS/2 Network Manager as an extension to the API.

In addition, OS/2 omits support for certain DOS services performed by other interrupts. Interrupts 25H and 26H, which perform direct-disk I/O by absolute-sector numbers, are totally banned in protected mode and are allowed only with restrictions in real mode. In real mode, removable disks can be read and written, but hard disks can only be read. This restriction has been added to prevent a real-mode task from changing a disk by absolute-sector access while a protected-mode background task is using the disk through the file system.

Another service not carried over to OS/2 is the multiplex interrupt 2FH, which allows communication between coresident processes in DOS. In its place, OS/2 provides a complete set of functions for interprocess communication (see table 9).

Human interface. Tables 3 through 5 show the OS/2 functions that replace the hodgepodge of techniques that are used under DOS to control the basic human-interface devices, namely, the keyboard, the mouse, and the screen. Because DOS support for these devices is, in general, anemic, programmers have traditionally eschewed the "official" API and dealt with it on a very low level—that is, either through the ROM BIOS or by accessing the device registers and buffers directly.

This unofficial API has enabled crafty programmers to create highly interactive programs, such as Lotus 1-2-3, but also has posed a serious challenge to OS/2 designers. The official (and only) API for OS/2 could not support these interactive programs if it simply duplicated the official DOS API; this would make the new operating system less attractive because OS/2 would end up with many of the problems that UNIX programmers encounter when they try to implement full-screen and mouse-driven applications. Eventually too much operating-system overhead would develop between the application programs and the hardware.

Thus OS/2 designers had to figure out how to provide the high performance of the unofficial DOS API to several application programs running at the same time. This was no mean feat, and the results are surprisingly good. OS/2 provides API functions that are equivalent to many of the BIOS interrupts dealing with the keyboard and screen (see tables 3 and 4).

In many cases, the new OS/2 functions are actually faster than their DOS predecessors, because OS/2 replaces the single-tasking ROM BIOS routines with more efficient multitasking versions. For applications requiring enhanced performance or graphics capability, OS/2 allows direct access to video buffers and device registers. Ac-

TABLE 7: *OS/2 Memory-management Functions*

FAMILY	INT 21H EQUIV.	NAME	DESCRIPTION
R		DosAllocHuge	Allocate huge memory block
R	48H	DosAllocSeg	Allocate segment
		DosAllocShrSeg	Allocate shared segment
F		DosCreateCSAlias	Create code segment alias for data segment
F	49H	DosFreeSeg	Free segment
F		DosGetHugeShift	Get shift parameter for huge blocks
		DosGetInfoSeg	Get address of system variable segment
		DosGetSeg	Get access to segment
		DosGetShrSeg	Get access to shared segment
		DosGiveSeg	Give access to segment
		DosLockSeg	Lock segment in memory
		DosMemAvail	Get size of largest free memory block
R		DosReallocHuge	Change size of huge memory block
R	4AH	DosReallocSeg	Change size of segment
F		DosSubAlloc	Allocate memory within segment
F		DosSubFree	Free memory within segment
F		DosSubSet	Set memory suballocation size
		DosUnlockSeg	Unlock segment

F = Full family-mode support
R = Restricted family-mode support

Besides allocating and freeing blocks of memory, these functions provide the various levels of memory sharing available in a protected-mode environment.

cess is controlled through locks so that several concurrent processes do not interfere with one another.

Video output. Three sample programs reproduced in the listings show three levels of video output supported by OS/2. Listing 1 (box1.c) is a C function that draws an empty box in text mode using the API's BIOS-like video services. Listing 2 (box2.c) shows how the C function can be written by direct access to the *logical video buffer*. Listing 3 (box3.c) uses the *physical video buffer*, which is display memory.

Each listing begins with declarations of the appropriate OS/2 program functions and the structures these functions use to pass data to and from the caller. Normally, the declarations are inserted by including the header file **subcalls.h**, but they are shown for the purposes of the examples given here. Static data declarations are specific to these examples and are not part of any standard header file.

Each variable in the static data area defines a display *cell*, which is a 16-bit data item with the video attribute in the high-order byte and the ASCII code of a character in the low-order byte. Here, the cells contain the box-drawing characters from the extended-ASCII character set of the IBM PC. For example, the variable **vhorz** is initialized with the value 07C4H; the high-order byte (07H) indicates white on black, and the low-order byte (C4H) is the ASCII code for a horizontal line.

The first example, the **box1** program in listing 1, uses two character-cell-oriented video functions, VioScrollUp and VioWrtCell, which are equivalents of similar services performed by the BIOS in real mode. VioScrollUp scrolls a rectangular area of the screen upward by a specified number of rows, filling the vacated rows with the specified cell data. This function takes seven arguments: the first four are the row-column coordinates of the four corners of the scrolled area, the fifth specifies the number of rows to scroll, the sixth points to the cell used to fill the scrolled area, and the last is the video-device handle (zero for default).

Once the area is cleared by scrolling, the borders of the box are drawn by several calls to VioWrtNCell. This function writes a cell value to a specified number of consecutive positions on the screen. Its first argument points to the cell value, the second is the number of cells to be written, the third and fourth specify the starting row and column, respectively, and the fifth argument is the video-device handle.

VioScrollUp performs the same function and takes the same input as interrupt 10H, function 6. VioWrtNCell

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TABLE 8: *OS/2 Multitasking Functions*

FAMILY	INT 21H EQUIV.	NAME	DESCRIPTION
		DosCreateThread	Create thread
R	4DH	DosCWait	Wait for child process termination
		DosEnterCritSec	Enter critical section
R	4BH	DosExecPgm	Execute program
R	00H, 4CH	DosExit	Exit program
		DosExitCritSec	Exit critical section
		DosExitList	Specify exit function list
		DosGetPid	Get process identification
		DosGetPrty	Get process priority
		DosKillProcess	Kill process
		DosMonClose	Disconnect device monitor
		DosMonOpen	Connect device monitor
		DosMonRead	Read from monitor structure
		DosMonReg	Register monitor buffers
		DosMonWrite	Write to monitor structure
		DosPtrace	Process debugging interface
		DosResumeThread	Restart thread
		DosSelectSession	Select foreground session
		DosSetPrty	Set process priority
		DosSetSession	Set session status
		DosSleep	Delay process execution
		DosStartSession	Start session
		DosStopSession	Stop session
		DosSuspendThread	Suspend thread execution
		DosSystemService	Request special process services
		DosTimerAsync	Start asynchronous timer
		DosTimerStart	Start interval timer
		DosTimerStop	Stop interval timer

R = Restricted family-mode support

Multitasking is one of the major attractions of OS/2. Functions are provided to control tasks at three integral levels: sessions, processes, and threads.

is, in effect, one or more calls to interrupt 10H, functions 2 (set cursor position) and 9 (write attribute and character). As with the corresponding BIOS functions, the calling program does not need to know the address of the video buffer, because the systems keep track of such hardware details.

The next example, **box2** in listing 2, shows a different version that writes directly to the logical video buffer. OS/2 allocates one of these buffers for each screen group, and the program can write to it even when executing in the background. Then when the session manager flips the screen group into the foreground, the logical video buffer is copied to the physical video buffer. This is essentially the same approach used by IBM's TopView and other DOS multitasking managers.

After **box2** computes the number of rows and columns in the requested box, it calls VioGetMode to obtain information about the current display mode. This function returns information in the ModeData structure. In most cases, OS/2 API functions return complex information in structures allocated by the application. Most of these structure formats are defined in the header files, and are available merely by including the appropriate header files (**doscalls.h** in this case).

The information returned by VioGetMode includes the number of rows and columns on the screen. This allows the row-column coordinates used by **box2** to be translated into linear offsets in the logical video buffer. In addition, because the character-cell dimensions of the screen are known, it is possible to verify that the requested box fits within the screen. (This also should have been done by **box1**, but was omitted for simplicity.)

Next, the buffer address and length are obtained using VioGetBuf. Then the program uses several **for** loops to insert character cells into the buffer, thereby clearing the box and drawing the border. Finally, the function VioShowBuf is called to notify OS/2 that the contents of the logical video buffer are ready to be copied to the physical video buffer.

One advantage of **box1** and **box2** is that either of them will execute even when the process is in the background and does not have access to the screen. The API functions called by **box1** automatically use the physical video buffer when they are in the foreground and the logical video buffer when in the background. The method illustrated by **box2** always uses the logical video buffer, but it informs OS/2 (by calling VioShowBuf) when the program reaches the foreground. The physical buffer can be updated at this point.

Although it is not obvious, the API services used in the preceding examples work only for text mode in that they are character- instead of pixel-oriented. But what if the display needs to be accessed at the pixel level, perhaps for a graphics application? The as-yet-unreleased Presentation Manager will address this issue. In the meantime, other methods are available for controlling the display at the pixel level, although these alternatives require a fair amount of programming. The OS/2 API includes functions that allow only foreground mode programs to read and write directly to the physical video buffer (see the example program **box3** in listing 3).

A program calls the VioScrLock function to request direct access to the physical video buffer. If this function is called from a program running in the background, it will not return until the program is returned to the foreground. When it does return, the calling program has complete control of the screen and is locked into the foreground; thus the user cannot switch away from it with the session manager. VioScrUnLock relinquishes this control.

VioGetPhysBuf maps a physical video buffer into the program's virtual address space so that the program can read and write to it directly. For protected-mode addressing, the function is passed the real-mode address and the length of a physical video buffer and returns one or more selectors (one for each 64KB physical segment or portion of a segment). The mapping operation is needed because a program can use only virtual addresses (or logical addresses) while in protected mode.

Physical video buffers are located between 640KB and 1MB in the real address space; their actual locations

TABLE 9: *OS/2 Interprocess Communication Functions*

FAMILY	NAME	DESCRIPTION
	DosCloseQueue	Close queue
	DosCloseSem	Close system semaphore
	DosCreateQueue	Create queue
	DosCreateSem	Create system semaphore
	DosFlagProcess	Set process external event flag
R	DosHoldSignal	Disable or enable signals
	DosMakePipe	Create pipe
	DosMuxSemWait	Wait for one of several semaphores
	DosOpenQueue	Open queue
	DosOpenSem	Open system semaphore
	DosPeekQueue	Peek at queue
	DosPurgeQueue	Purge queue
	DosQueryQueue	Query size of queue
	DosReadQueue	Read from queue
	DosSemClear	Clear semaphore
	DosSemRequest	Request semaphore
	DosSemSet	Set semaphore
	DosSemSetWait	Set semaphore and wait for clear
	DosSemWait	Wait for semaphore to clear
	DosSendSignal	Send signal
R	DosSetSigHandler	Set signal handler
	DosWriteQueue	Write to a queue

R = Restricted family-mode support

Although concurrent tasks are normally protected from one another, they can be designed to communicate. DOS supports no equivalent functions.

TABLE 10: *OS/2 Miscellaneous Functions*

FAMILY	INT 21H EQUIV.	NAME	DESCRIPTION
F		BadDynLink	Called on bad dynamic link
F		DosBeep	Honk horn
F		DosCaseMap	Case-map character string
R	59H	DosErrClass	Classify error code
R		DosError	Enable hard error processing
		DosFreeModule	Free dynamic link module
F		DosGetCollate	Get collating sequence table
	66H	DosGetCp	Get process code page
R	38H	DosGetCtryInfo	Get country-dependent information
F	2AH,2CH	DosGetDateTime	Get system date and time
	65H	DosGetDBCSEv	Get dual-byte character set
F		DosGetEnv	Get environment string address
F		DosGetMachineMode	Get processor mode
		DosGetModHandle	Get dynlink module handle
		DosGetModName	Get dynlink module name
		DosGetProcAddr	Get dynlink proc address
F	30H	DosGetVersion	Get OS version number
		DosLoadModule	Load dynamic link module
F		DosScanEnv	Scan environment strings
	66H	DosSetCp	Set process code page
F	2BH,2DH	DosSetDateTime	Set system date and time
F	25H	DosSetVec	Specify exception handler

F = Full family-mode support
R = Restricted family-mode support

Some of the most useful functions do not fit into any previous groups. Except for dynamic-link functions, most are DOS function equivalents or extensions.

depend on the hardware used. To determine which video adapter is present, the program calls VioGetMode, which, in addition to other information, returns a bit flag indicating if a Monochrome Display Adapter (MDA) or a Color Graphics Adapter (CGA) is present. The program then uses a real buffer address of B000:0000H for the former and B800:0000H for the latter.

It is important not to attempt to access the physical buffer through its real-memory address when the process is running in protected mode. If this occurs, OS/2 probably will abort the process for a memory-protection error. However, some of the process data might be mapped into those virtual addresses, in which case a protection violation would not occur, but some data could be mutilated.

The example in listing 3 barely scratches the surface of the question of protected-mode access to the physical video buffer. For example, a program that uses the Enhanced Graphics Adapter (EGA) also must have access to the EGA registers. This can be accomplished by using the function DosPortAccess. In addition, the session manager does not automatically save and restore graphics information and video modes when it switches a process from foreground to background and vice versa. However, by creating threads and then calling the functions VioModeWait and VioSavRedrawWait, OS/2 can be made to indicate when these switches occur. The threads can wait for a foreground/background switch, then they can save and restore the video modes and the graphics buffers.

The **Vio** function group also includes rudimentary support for pop-up message windows through VioPopUp and VioEndPopUp. VioPopUp saves the current screen's contents and provides immediate access to the screen, even if the process is not executing in the foreground. In fact, a "super foreground" mode comes into play, providing exclusive access to keyboard and screen until VioEndPopUp is called.

This feature typically would be used to notify the user of some condition requiring immediate user intervention, regardless of where the program is executing. OS/2 uses this feature in order to implement a fancy pop-up version of the dreaded DOS message "Abort, Retry, Ignore."

Files and memory management. The file I/O services of OS/2 (see table 6) are similar to those provided with DOS, which is not surprising because the file systems in DOS and OS/2 are identical.

The most significant OS/2 enhancement is its ability to perform asynchronous I/O operations—the program can initiate a file read or write and continue doing other work while the I/O subsystem carries out the operation. Synchronization between the calling process and the asynchronous I/O function is achieved by means of a *RAM semaphore*, a form of interprocess communication described later.

Table 7 lists the OS/2 memory-management services. This category covers functions that manage memory blocks contained in a single segment and in multiple segments, that enable the sharing of memory blocks by cooperating processes, and that control access to discardable memory blocks.

A process uses DosAllocSeg, DosFreeSeg, and DosReallocSeg to acquire, release, and resize blocks no larger than one segment (up to 64KB). These three functions have direct equivalents in DOS, as shown in the table. OS/2 adds three new services called DosSubAlloc, DosSubFree, and DosSubSet, which offer a capability similar to the **malloc** and **free** functions commonly used by C programmers to suballocate large blocks into smaller ones. DosAllocHuge, DosFreeSeg, and DosReallocHuge are used to acquire, release, and resize blocks larger than 64KB. DosFreeSeg also works with single-segment blocks.

In reality, allocating a huge block involves allocating the several 64KB segments that make up the block. DosGetHugeShift returns a value that indicates the relationship among these several segments; the value is the logarithm to the base 2 of the difference between the segment portion of the addresses of successive segments in the block. In protected mode, the value returned is 4, meaning that 2^4 or 16 must be added to one segment selector to obtain the one for the next segment in the block. In real mode, the value returned by DosGetHugeShift is 12; 2^{12} is 1000H, or the length in paragraphs of a physical segment.

The entire concept of protected mode is based on the premise that the memory allocated to one process is not accessible to the other process. However, two or more cooperating processes can arrange to share each other's memory for rapid exchange of data. Sharing memory requires that the same segment descriptors appear in the tables of each sharing process. Then, when one process writes into the shared area, the change is immediately "seen" by the other processes.

TABLE 11: *OS/2 Equivalents of DOS INT 21H Functions*

INT 21H FUNCTION	OS/2 FUNCTION	DESCRIPTION
00H	DosExit	Terminate
01H	KbdCharIn	Keyboard input
02H	VioWrtTTY	Video output
03H		Auxiliary input
04H		Auxiliary output
05H		Printer output
06H		Direct console I/O
07H	KbdCharIn	Direct keyboard input without echo
08H		Keyboard input without echo
09H	VioWrtTTY	Print string
0AH	KbdStringIn	Buffered keyboard input
0BH	KbdPeek	Check keyboard input status
0CH		Clear keyboard buffer and execute
0DH	DosBufReset	Reset disk
0EH	DosSelectDisk	Select disk
0FH		Open file with FCB
10H		Close file with FCB
11H		Search for first directory entry with FCB
12H		Search for next directory entry with FCB
13H		Delete file with FCB
14H		Sequential read with FCB
15H		Sequential write with FCB
16H		Create file with FCB
17H		Rename file with FCB
18H		Reserved
19H	DosQCurDisk	Identify current disk
1AH		Set disk transfer address
1BH		Get allocation info. for current disk
1CH		Get allocation info. for specified disk
1DH		Reserved
1EH		Reserved
1FH		Reserved
20H		Reserved
21H		Random read with FCB
22H		Random write with FCB
23H		Get file size with FCB
24H		Set relative record field in FCB
25H	DosSetVec	Set interrupt vector
26H		Create new program segment
27H		Random block read with FCB
28H		Random block write with FCB
29H		Parse file name in FCB
2AH	DosGetDateTime	Get system date
2BH	DosSetDateTime	Set system date
2CH	DosGetDateTime	Get system time
2DH	DosSetDateTime	Set system time
2EH	DosSetVerify	Set/reset disk verify mode
2FH		Get disk transfer address
30H	DosGetVersion	Get version number
31H		Terminate and stay resident
32H		Reserved
33H	DosHoldSignal	Set/reset abort key check
34H		Reserved
35H		Get interrupt vector
36H	DosQFSInfo	Get disk free space
37H		Reserved
38H	DosGetCtryInfo	Set/get country information

INT 21H FUNCTION	OS/2 FUNCTION	DESCRIPTION
39H	DosMkDir	Make directory
3AH	DosRmDir	Remove directory
3BH	DosChDir	Change current directory
3CH	DosOpen	Create file
3DH	DosOpen	Open file
3EH	DosClose	Close file
3FH	DosRead	Read from file
40H	DosWrite	Write to file
41H	DosDelete	Delete file
42H	DosChgFilePtr	Change file position
43H	DosQFileMode	Get file mode
43H	DosSetFileMode	Change file mode
44H	DosDevIOCtl	Execute device control operation
45H	DosDupHandle	Duplicate file handle
46H	DosDupHandle	Force file handle duplication
47H	DosQCurDir	Get current directory
48H	DosAllocSeg	Allocate memory segment
49H	DosFreeSeg	Free memory segment
4AH	DosReallocSeg	Change segment size
4BH	DosExecPgm	Load and execute program
4CH	DosExit	Terminate
4DH	DosCWait	Get child process return code
4EH	DosFindFirst	Find first matching file in directory
4FH	DosFindNext	Find next matching file in directory
50H		Reserved
51H		Reserved
52H		Reserved
53H		Reserved
54H	DosQVerify	Get disk verify mode
55H		Reserved
56H	DosMove	Rename/move file
57H	DosQFileInfo	Get file's date and time
57H	DosSetFileInfo	Set file's date and time
58H		Reserved
59H	DosErrClass	Get extended error information
5AH		Create unique file
5BH	DosOpen	Create new file
5CH	DosFileLocks	Lock/unlock file section
5DH		Reserved
5E00H		Get machine name
5E01H		Set printer initialization string
5E02H		Get printer initialization string
5F02H		Get redirection list entry
5F03H		Redirect device
5F04H		Cancel redirection
60H		Reserved
61H		Reserved
62H		Get program segment prefix address
63H		Reserved
64H		Reserved
65H	DosGetDBCSEv	Get extended country information
66H	DosGetCP	Get global code page
66H	DosSetCP	Set global code page
67H	DosSetMaxFH	Set handle count
68H	DosBufReset	Commit file

Most documented DOS services have OS/2 equivalents. Major exceptions are DOS services carried over from CP/M, such as those for FCB-oriented file I/O.

Shared memory is allocated by calling DosAllocShrSeg, which is the same as DosAllocSeg, except that it allows the programmer to name the allocated segment. Other processes then can gain access to the segment by calling DosGetShrSeg with the same name.

Another way to allocate a segment for sharing is to call DosAllocSeg, followed by DosGiveSeg. In the latter call, the program first identifies the process that is to share the segment; subsequently, the program sends that process a handle, which it, in turn, passes on to the DosGetSeg function in order to gain access to the segment.

Obviously, the sharing processes must have some prearranged way of cooperating. The two processes must agree either on the name of the shared segment or on the method by which the segment handle will be passed.

Whenever a segment is allocated by using any of the above methods, the segment can be identified as "discardable." Thus the operating system can, in the interest of efficiency, reclaim the segment whenever it is not locked. DosLockSeg must be called in order to use the segment. If that function returns an error code, indicating that the segment has been discarded, the program must call DosReallocSeg to get the memory back. DosUnlockSeg then should be called when the segment is no longer required.

Discardable segments can be used to store useful, but nonessential data, such as disk-cache buffers. Unlocking a segment is a conditional deallocation since data in that segment might still be in memory when the segment is next locked. If this is so, the program can avoid the overhead of reallocating memory and reconstructing data (perhaps with time-consuming I/O).

Task management. Because the creation and management of concurrently executing tasks is one of its distinguishing features, OS/2 provides a copious repertoire of services for multitasking control (see table 8). These services manage the various levels of tasks within OS/2, including sessions, processes, threads, and monitors. Task management is only summarized here; for more details on this topic, see "Multiple Tasks," Steven Armbrust and Ted Forgeron, this issue, p. 90.

A *session* (also called a screen group) is a set of one or more tasks with one logical-screen buffer and one keyboard. Only tasks in the same session can display windows on the screen simultaneously. The user typically starts a session by means of the

session manager, a utility program supplied with OS/2. The four functions, DosStartSession, DosStopSession, DosSelectSession, and DosSetSession, generally are called only by the session manager; however, these functions are available so that, if necessary, the programmer can create a different session manager for special occasions.

A *process* is normally regarded as a program and associated with an executable file that can be loaded either by a user command or by another process. Each screen group consists of a primary, or parent, process typically started by the user and possibly several child processes started by other processes within the group.

Each process is created by using DosExecPgm, which is analogous to the DOS Exec but with one important difference: the newly created child process runs concurrently with its parent; that is, the call to DosExecPgm returns immediately, not when the child process terminates. If the parent process must wait for the child to terminate, it calls DosCWait. Process creation is usually time consuming because OS/2 must load a program file and connect it to whatever dynamic-link libraries it uses. Along the way, it must perform many resource-allocation steps in order to secure both the memory and the standard I/O resources that would be required later on by the process.

Creating a *thread*, or separate execution path, is somewhat similar to calling a subroutine within a program, but then continuing to execute the code while the subroutine executes concurrently. All the threads of one process share memory, files, and data. Establishing a thread is much simpler than creating a process, because no program-loading and complex resource-allocation steps are required.

A thread is the dispatchable object in OS/2. When the OS/2 scheduler decides the order of priority for CPU use, it scans a list of threads ready to execute and dispatches control to the highest-priority thread, regardless of the process to which it belongs.

Threads terminate by calling DosExit. When the last thread in a process terminates, the process terminates automatically. A parent process also can force one of its child processes to terminate by DosKillProcess. In addition, any process can use DosExitList to establish a list of internal functions to be called during termination. Usually these perform clean-up actions such as releasing resources that might be needed by other processes.

The set of functions with names that begin with DosMon is used to attach a thread to a character device (such as the keyboard, screen, or printer) to monitor the data stream entering or exiting the device. These facilities replace the chaotic schemes used by DOS TSRs implementing hotkey utilities and output processors.

When a thread is installed as a monitor, it can process data from the device I/O stream before these data reach the process requesting input or the device that is the destination of the output. In an input stream, the monitor then can replace the original data, or it simply can delete the data after taking appropriate action. The former occurs if the monitor is a keyboard macro processor, such as RoseSoft's ProKey or Borland's SuperKey, that expands a single keystroke into a string of characters. The latter applies if the monitor is a pop-up desk accessory, such as Borland's SideKick or Lotus Metro, that is activated by a hot key but that does not, however, pass that key on.

For output, a monitor could act as a print spooler, collecting characters for the printer at high speed, notifying the sending program that the printer has accepted them, saving them in a buffer in memory or on disk, and later doling them out to the printer at whatever speed that the device could tolerate. The spooler that is supplied with the initial version of OS/2 is implemented in just this fashion.

Interprocess communication. Along with its multitasking capabilities, OS/2 has a rich set of interprocess communication services (table 9) that encompasses all the techniques popularized in systems such as UNIX and includes signals (or event flags), semaphores, pipes, queues (also called message lists or mailboxes), and shared memory.

A signal is essentially a one-bit message sent from one process to another. A process calls DosFlagProcess or DosSendSignal to send a signal to another process. The receiving process calls DosSetSigHandler to identify the routine to execute when a signal is received and DosHoldSig to enable or disable the receipt of the signal. The most common source of signals is OS/2's announcing that the user has pressed the abort or interrupt keys.

A semaphore also is essentially a one-bit message, but it is more flexible than a signal. Either *system* semaphores or *private* semaphores can be created. A system semaphore has a name and can be accessed by any process that knows the name. A private semaphore,

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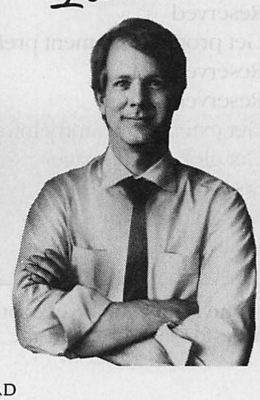

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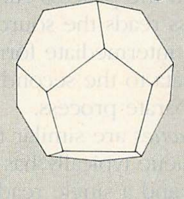

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or, in other words, a RAM semaphore, simply is a 32-bit value that is allocated in memory space and shared by all of the cooperating threads.

A semaphore typically provides orderly access to some shared resource. For example, if several cooperating threads are adding data to a shared buffer, a semaphore could be associated with the buffer. Then each thread would call DosSemRequest before writing into the buffer and call DosSemClear when it was finished. The former call does not return until the semaphore is clear (signifying that no other process is writing to the buffer), although a time-out value on the request can be specified to avoid a lockup if the program that currently owns the semaphore goes west.

OS/2 also allows semaphores to be used as signals or event flags since one process can set a semaphore and then wait until another process clears it. This is the mechanism used to determine when an asynchronous file I/O is complete. Before calling the I/O function, a thread calls DosSemSet to set a RAM semaphore. It then calls functions DosReadAsynch or DosWriteAsynch, passing the address of the semaphore as one of the parameters, and continues with other processing while the file activity proceeds concurrently. When the I/O is complete, OS/2 clears the semaphore. The thread requesting the I/O can determine when the I/O has completed by calling DosSemWait, which does not return until the specified semaphore is clear.

DosMuxSemWait also can synchronize multiple threads. It receives a list of semaphores, waits until one of them is cleared, then returns the index of the cleared semaphore.

Pipes can be compared to byte stream files that are simultaneously being written by one process while they are being read by another. In fact, once that a pipe is established by using the DosMakePipe function, it can be accessed through the normal file I/O read and write functions.

Pipes typically are used to connect filter processes, which simply read data from an input file, filter the data, then write the new data to an output file. A good example is a two-pass compiler in which the process running as the first pass reads the source file, converts it to an intermediate form, and pipes those data to the second pass, running as a separate process.

Queues are similar to pipes in that each queue typically has one or more writers and a single reader. However, the data on a queue are structured into records, and the reader can remove the records in any order. With a pipe, the reader can remove the data only in the order in which they were written, and a pipe provides no system-supported way for the reader to discern the records within the data stream.

Whereas queues are arguably the most flexible of the OS/2 interprocess communication facilities, they also are the most difficult to use, because each record placed on a queue must reside in a shared segment accessible to both the writer and the reader.

Its easy extendibility could lead OS/2 into a fertile new market where DOS has not done very well—namely, customized systems.

Miscellaneous functions. Table 10 lists the other assorted API functions. DosFreeModule, DosGetModHandle, DosGetModname, DosGetProcAddr, and DosLoadModule provide direct control of the loading and deletion of dynamically linked modules and would be used by a program controlling dynamic linking at call time. Load time is handled automatically by OS/2.

BadDynLink is called by the family-mode stub if the program attempts to use a nonfamily API function while in DOS mode. The standard version aborts the program, but the program can replace it with another for different error handling.

The functions DosGetVersion and DosGetMachineMode provide additional support for family-mode programs. The former function can be used to distinguish between DOS and OS/2. The version number of the initial release of OS/2 is 10; when it is called by a family-mode program running under DOS, the first function returns the same value as DOS function 30H. The second function distinguishes between the real and protected modes of OS/2 and also indicates real mode if it is called under DOS.

DosCaseMap, DosGetCollate, DosGetCtryInfo, and DosGetDBCSEv are the primary ways in which an application can be adapted to work in different countries using the appropriate character sets, currency and date formats, and so on. Although DOS provides similar services, OS/2 has expanded them considerably.

FLEXIBLE EXTENSIONS

The addition of new features such as the Network Manager and the Presentation Manager will extend the basic definition of OS/2 presented in version 1.0. One of the main strengths of the new API service protocol is that it can be extended gracefully.

Adding a set of features involves writing a set of functions that conform to the OS/2 protocol described in this article, then incorporating them into a link-time definition library and a run-time dynamic-link library. To make the new capabilities more accessible to developers, it is desirable to provide header files declaring the functions and their data structures. So far, specifications conforming to this scheme have been released by Microsoft for the Network Manager and jointly by IBM and Microsoft for the Presentation Manager. IBM also has announced its intention to develop future enhancements to support communications and database access. The OS/2 design allows extensions to be incorporated into the system automatically with no changes to the existing components. Therefore, anyone can develop extensions, not just the original developers.

This easy extendibility could lead OS/2 into a fertile new market where DOS has not done very well—namely, customized systems. Although DOS has been adequate for desktop workstations, it has not been easily adapted for use in such realtime applications as point-of-sale systems, factory automation, and message switching. With the flexible OS/2 API, the developer can add the services specific to such applications with facility. He can smoothly substitute custom versions of OS/2 modules such as the session manager and command processor because they use the standard API—and not some mysterious interface such as the one between DOS and COMMAND.COM. Finally, OS/2's features make it attractive for customized applications with real-time processing requirements.

Even straight out of the box, OS/2 is vastly superior to DOS. Its true strength, however, lies not in its present form but in its potential for growth. Given OS/2 API's intrinsic flexibility, its horizons are boundless.

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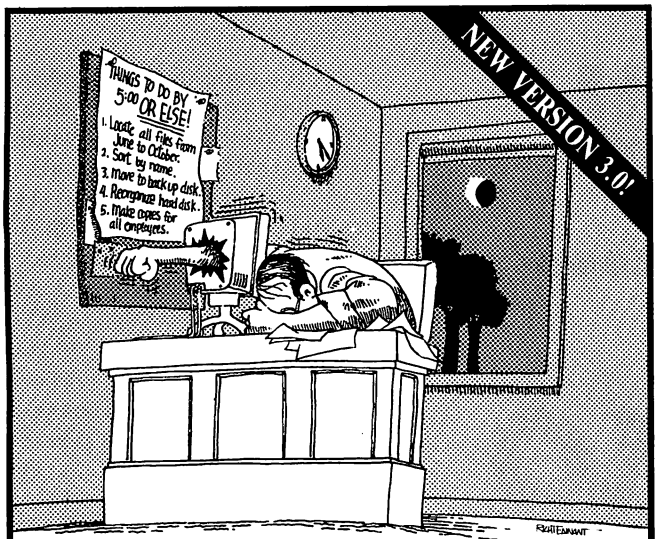

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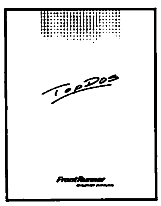

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LISTING 1: BOX1.C

```
/* BOX1 function:  draw a box using VIO screen functions */

/*  External declarations for OS/2 API functions. */

extern far pascal VIOSCROLLUP(short,short,short,short,short,
                              short far *,short);
extern far pascal VIOWRTNCELL(short far *,short,short,short,short);

/* Static data */

static unsigned short vhorz = 0x07c4;    /* horizontal line */
static unsigned short vvert = 0x07b3;    /* vertical line */
static unsigned short vulc = 0x07da;     /* upper left corner */
static unsigned short vllc = 0x07c0;     /* lower left corner */
static unsigned short vurc = 0x07bf;     /* upper right corner */
static unsigned short vlrc = 0x07d9;     /* lower right corner */
static unsigned short vfill = 0x0720;    /* fill value */

/* synopsis        error = box1(d);
 *                 int error;
 *                 unsigned short *d;
 *
 * description     Draws a box on the screen using the line
 *                 characters defined above in the static data area.
 *                 The interior of the box is reset to the fill value.
 *
 *                 The caller must pass a pointer to an array of 4
 *                 integers arranged as follows:
 *
 *                    d[0] = upper left row number
 *                    d[1] = upper left column number
 *                    d[2] = lower right row number
 *                    d[3] = lower right column number
 *
 *                 If this array defines an invalid box, then the
 *                 function returns -1.  Otherwise, it returns 0.
 */

box1(d)
unsigned short *d;
{
int i,rows,cols;

rows = d[2] - d[0] - 1;          /* compute rows within box */
if(rows <= 0) return(-1);        /* fail if no rows */

cols = d[3] - d[1] - 1;          /* compute columns within box */
if(cols <= 0) return(-1);        /* fail if no columns */

VIOSCROLLUP(d[0],d[1],d[2],d[3],rows+2,     /* clear the box */
     (short far *)(&vfill),0);

              /* Draw the four corners */
VIOWRTNCELL((short far *)(&vulc),1,d[0],d[1],0);
VIOWRTNCELL((short far *)(&vurc),1,d[0],d[3],0);
VIOWRTNCELL((short far *)(&vllc),1,d[2],d[1],0);
VIOWRTNCELL((short far *)(&vlrc),1,d[2],d[3],0);

              /* Draw upper/lower borders */
VIOWRTNCELL((short far *)(&vhorz),cols,d[0],d[1]+1,0);
VIOWRTNCELL((short far *)(&vhorz),cols,d[2],d[1]+1,0);

              /* Draw left/right borders */
for(i = 0; i < rows; i++)
  {
  VIOWRTNCELL((short far *)(&vvert),1,d[0]+i+1,d[1],0);
  VIOWRTNCELL((short far *)(&vvert),1,d[0]+i+1,d[3],0);
  }
return(0);                      /* success return */
}
```

LISTING 2: BOX2.C

```
/* BOX2 function: draw box in logical video buffer */

/*  External declarations for OS/2 API functions. */

extern far pascal VIOGETBUF(long far *, short far *, short);
extern far pascal VIOGETMODE(struct ModeData far *, short);
```

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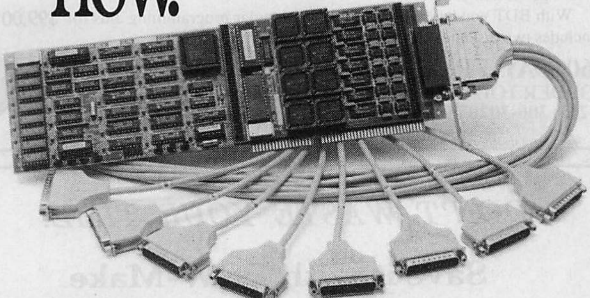

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```
extern far pascal VIOSHOWBUF(short,short,short);

struct ModeData                   /* data area for VIOGETMODE */
  {
  short length;                   /* length of structure */
  char type;                      /* display type */
  char colors;                    /* number of colors */
  short cols;                     /* number of text columns */
  short rows;                     /* number of text rows */
  short pcols;                    /* number of pixel columns */
  short prows;                    /* number of pixel rows */
  };

/* Static data */

static unsigned short vhorz = 0x07c4;    /* horizontal line */
static unsigned short vvert = 0x07b3;    /* vertical line */
static unsigned short vulc = 0x07da;     /* upper left corner */
static unsigned short vllc = 0x07c0;     /* lower left corner */
static unsigned short vurc = 0x07bf;     /* upper right corner */
static unsigned short vlrc = 0x07d9;     /* lower right corner */
static unsigned short vfill = 0x0720;    /* fill character */

/* synopsis          error = box2(d);
 *                   int error;
 *                   unsigned short *d;
 *
 * description       Same as box1.  Also returns -1 if any OS/2
 *                   function returns an error.
 */

box2(d)
unsigned short *d;
{
int i,j,rows,cols;                /* miscellaneous */
int trx,brx;                      /* index to top and bottom rows */
short far *b;                     /* logical video buffer pointer */
short s;                          /* size of video buffer */
struct ModeData mode;             /* data area for VIOGETMODE */

rows = d[2] - d[0] - 1;           /* compute rows within box */
if(rows <= 0) return(-1);         /* fail if no rows */

cols = d[3] - d[1] - 1;           /* compute columns within box */
if(cols <= 0) return(-1);         /* fail if no columns */

mode.length = sizeof(struct ModeData);          /* get video mode */
if(VIOGETMODE((struct ModeData far *)(&mode),0)) return(-1);

if(d[2] >= mode.rows) return(-1);          /* fail if off screen */
if(d[3] >= mode.cols) return(-1);               /* ditto */

trx = d[0] * mode.cols + d[1];       /* compute top row index */
brx = d[2] * mode.cols + d[1];       /* compute bottom row index */

                                     /* get video buffer address */
if(VIOGETBUF((long far *)(&b),(short far *)(&s),0))
     return(-1);

                    /* Insert characters into video buffer */

b[trx] = vulc;                    /* upper left corner */
b[brx] = vllc;                    /* lower left corner */
for(i = 1; i <= cols; i++)        /* top and bottom borders */
  {
  b[trx+i] = vhorz;
  b[brx+i] = vhorz;
  }
b[trx+i] = vurc;                  /* upper right corner */
b[brx+i] = vlrc;                  /* lower right corner */
for(j = 1; j <= rows; j++)        /* left and right borders */
  {
  trx += mode.cols;
  b[trx] = vvert;
  for(i = 1; i <= cols; i++)      /* and also erase interior of box */
    b[trx+i] = vfill;
  b[trx+i] = vvert;
  }
```

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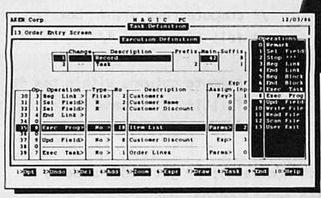

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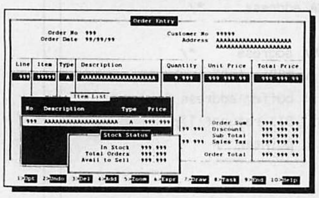

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```
VIOSHOWBUF(0,s,0);              /* update the screen if foreground */

return(0);                      /* success return */
}
```

LISTING 3: BOX3.C

```
/* BOX3 function: draw box in physical video buffer */

/*  External declarations for OS/2 API functions. */

extern far pascal VIOGETPHYSBUF(struct BufData far *, short);
extern far pascal VIOGETMODE(struct ModeData far *, short);
extern far pascal VIOSCRLOCK(short,char far *,short);
extern far pascal VIOSCRUNLOCK(short);

struct BufData                  /* data area for VIOGETPHYSBUF */
  {
  unsigned long real;           /* real address of display buffer */
  unsigned long length;         /* length of display buffer */
  unsigned short prots[2];      /* protected-mode selector(s) */
  };

struct ModeData                 /* data area for VIOGETMODE */
  {
  short length;                 /* length of structure */
  char type;                    /* display type */
  char colors;                  /* number of colors */
  short cols;                   /* number of text columns */
  short rows;                   /* number of text rows */
  short pcols;                  /* number of pixel columns */
  short prows;                  /* number of pixel rows */
  };

/* Static data */

static unsigned short vhorz = 0x07c4;     /* horizontal line */
static unsigned short vvert = 0x07b3;     /* vertical line */
static unsigned short vulc = 0x07da;      /* upper left corner */
static unsigned short vllc = 0x07c0;      /* lower left corner */
static unsigned short vurc = 0x07bf;      /* upper right corner */
static unsigned short vlrc = 0x07d9;      /* lower right corner */
static unsigned short vfill = 0x0720;     /* fill character */

/* synopsis        error = box3(d);
 *                 int error;
 *                 unsigned short *d;
 *
 * description     Same as box2
 */

box3(d)
unsigned short *d;
{
int i,j,rows,cols;                        /* miscellaneous */
int trx,brx;                              /* index to top and bottom rows */
union {                                   /* physical video buffer pointer */
  short far *x;
  unsigned short y[2];
  } b;
struct BufData buf;                       /* storage area for buffer data */
struct ModeData mode;                     /* storage area for mode data */

rows = d[2] - d[0] - 1;                   /* compute rows within box */
if(rows <= 0) return(-1);                 /* fail if no rows */

cols = d[3] - d[1] - 1;                   /* compute columns within box */
if(cols <= 0) return(-1);                 /* fail if no columns */


mode.length = sizeof(struct ModeData); /* get video mode */
VIOGETMODE((struct ModeData far *)(&mode),0);

if(d[2] >= mode.rows) return(-1);         /* fail if off screen */
if(d[3] >= mode.cols) return(-1);         /* ditto */

trx = d[0] * mode.cols + d[1];            /* compute top row index */
brx = d[2] * mode.cols + d[1];            /* and bottom row index */

if(mode.type & 1)                         /* if type bit 0 is set... */
  buf.real = 0xb8000;                     /* ... use CGA address     */
else
  buf.real = 0xb0000;                     /* else use MDA address     */
buf.length = 25 * 80 * 2;                 /* len = 25 rows*80 cols*2 bytes */
                                          /* get physical buffer address */
if (VIOGETPHYSBUF((struct BufData far *)(&buf),0)) return(-1);
b.y[0] = 0;                               /* form a valid pointer */
b.y[1] = buf.prots[0];

                                          /* wait for foreground */
if (VIOSCRLOCK(1,(char far *)(&i),0)) return(-1);

                                          /* put characters to buffer: */
b.x[trx] = vulc;                          /* upper left corner */
b.x[brx] = vllc;                          /* lower left corner */
for(i = 1; i <= cols; i++)                /* top and bottom borders */
  {
  b.x[trx+i] = vhorz;
  b.x[brx+i] = vhorz;
  }
b.x[trx+i] = vurc;                        /* upper right corner */
b.x[brx+i] = vlrc;                        /* lower right corner */
for(j = 1; j <= rows; j++)                /* left and right borders */
  {
  trx += mode.cols;
  b.x[trx] = vvert;
  for(i = 1; i <= cols; i++)              /* and also erase interior of box */
    b.x[trx+i] = vfill;
  b.x[trx+i] = vvert;
  }

VIOSCRUNLOCK(0);                          /* unlock the screen */
return(0);                                /* success return */

  }
```


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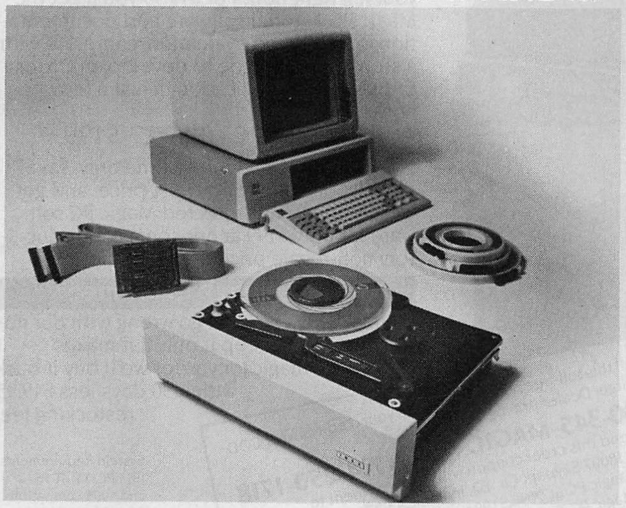

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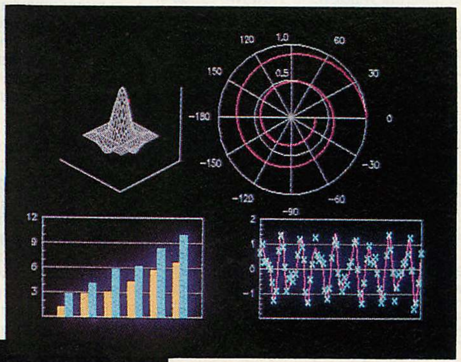

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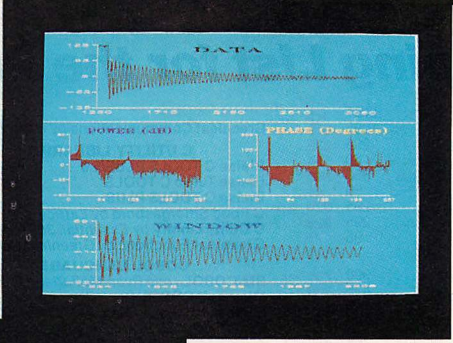

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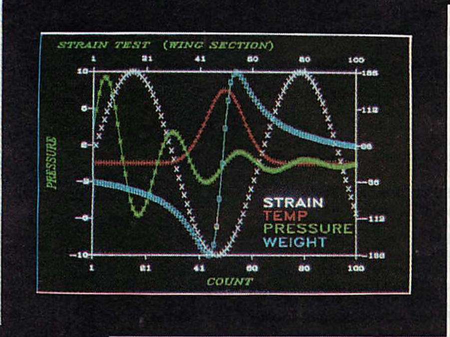

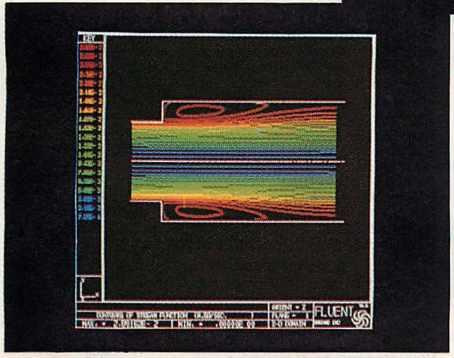

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r-tree: Adds the ability to produce ad hoc reports from files maintained by c-tree (v. 4.1 and up). Link a file description to the r-tree™ library, and use any text editor to write report scripts with no further C coding. Reports can access data in several files, select on criteria, join findings into new logical records, sort them, calculate new fields and columns, tabulate by control breaks. Comes in source, same portability as c-tree, and fits any compiler.

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c-tree:	**$395**	**$329**	**$541**
r-tree:	**$295**	**$245**	

WINDOWS for DATA

FIRST PRIZE!

M'Soft Windows Compatible

"Only one package can be easily recommended" said *Computer Language* (June '87) reviewing nine window and data entry products for C. Complete field level functions specify prompt string, field length, data type, screen location, picture, target variable, entry rules, help messages, even functions to call for validation once data keyed in.

Windows for C is a subset. No data entry but all windowing functions. Unlimited windows can be made either to pop up or permanently overwrite the screen, scroll and highlight lists vertically and horizontally. Specify Compiler. Windows for Data: List **$395**, Ours **$315.** Windows for C: List **$245**, Here **$216.**

ESSENTIAL C UTILITY LIBRARY

400 Functions, 30c Each

You've probably seen the speed and power of Essential's C function library without knowing it. Software greats have been using it for some time to give today's top products pizazz and panache.

Now grown to 400 functions Essential produces pop-up menus, saves and restores screens and windows to disk or memory in as little as 1/10th second, and claims the fastest video output available. Library has 50 business graphics functions, 40 string handlers, 28 functions for printers, 18 for mice, 11 for time and date, DOS interface functions for disk error trapping, directory and file creation and management, lots more. Everything in source, including sample programs. We have versions with pre-built libraries for the well-known C compilers, and a source code librarian is supplied for rolling your own.

	List:	PC Brand:
C Utility Library	**$185**	**$119**
Essential Graphics	**$250**	**$183**
Essential Communications	**$185**	**$125**
with Breakout Debugger	**$250**	**$189**

Shopping List for the Power Workbench

	LIST	US
ARITY PRODUCTS		
Arity Combination Package	1095	979
Expert System Development Pkg	295	229
File Interchange Toolkit	50	44
PROLOG Compiler & Interpreter	650	569
Screen Design Toolkit	50	44
SQL Development Package	295	229
Arity PROLOG Interpreter	295	229
Arity Standard Prolog	95	77
AI-EXPERT SYSTEMS		
Autointelligence *by IntelligenceWare*	990	739
Experteach II *by IntelligenceWare*	475	339
EXSYS *Development Software by EXSYS*	395	309
EXSYS Runtime System	600	469
Insight 2+ *by Level Five Research*	485	379
Intelligence/Compiler *IntelligenceWare*	990	739
AI-LISP LANGUAGE		
IQCLISP *by Integral Quality*	300	Call
IQLISP *by Integral Quality*	270	Call
Microsoft LISP *Common LISP*	250	199
TransLISP *from Solution Systems*	95	Call
TransLISP PLUS *from Solution Systems*	195	Call
AI-PROLOG LANGUAGE		
APT *Active Prolog Tutor from Solution Sys.*	65	Call
MPROLOG Language Primer *LOGICWARE*	50	45
MPROLOG P500 *by LOGICWARE*	495	395
MPROLOG P550 *by LOGICWARE*	220	175
Prolog-86 *from Solution Systems*	125	Call
Prolog-86 Plus *from Solution Systems*	250	Call
Turbo PROLOG *by Borland Int'l*	100	63
Turbo PROLOG Toolbox *by Borland Int'l*	100	64
ASSEMBLERS & DEBUGGERS		
Advanced Trace-86 *Morgan Debugger*	175	119
C-Sprite Debugger *by Lattice, source level*	175	139
Microsoft Macro Assembler *with Utilities*	150	109
PASM86 *by Phoenix, Macro Assembler*	195	138
Periscope I Debugger...*The Periscope Co.*	345	289
Periscope II *with NMI Breakout Switch*	175	139
Periscope II-X *software only*	145	105
Periscope III *with Advanced Board...New*	995	Call
BASIC LANGUAGE		
Microsoft BASIC Interpreter *for XENIX*	350	295
Microsoft QuickBASIC Compiler...*3.0*	99	79
BORLAND PRODUCTS		
Reflex & Reflex Workshop	200	129
Reflex *Data Base System*	150	89
Reflex Workshop	70	45
Turbo Basic...*New*	100	64
Turbo C Compiler...*New*	100	64
Turbo Lightning	100	64
Turbo Pascal & Tutor...*New*	125	85
Turbo Pascal with 8087 & BCD	100	64
Turbo PROLOG Compiler	100	63
Turbo PROLOG Toolbox	100	64
Turbo Tutor	40	28
C COMPILERS		
C86 PLUS *by Computer Innovations...New*	497	397
Lattice C Compiler *from Lattice*	500	299
Let's C Compiler *by Mark Williams*	75	55
with CSD Source Level Debugger	125	90
MWC-86: Mark Williams C Development	495	369
Microsoft C Compiler *...4.0*	450	295
Turbo C Compiler *by Borland...New*	100	64
C INTERPRETERS		
C-Terp *by Gimpel Software*	300	249
Instant C *by Rational Systems*	500	395
Interactive-C *by IMPACC with debugging*	249	219
RUN/C Professional *from Lifeboat*	250	185
COMMUNICATIONS		
Asynch Manager *by Blaise, for C or Pascal*	175	135

	LIST	US
Greenleaf Communications *by Greenleaf*	185	139
C UTILITY LIBRARIES		
Blaise C TOOLS PLUS/5.0	129	99
Blaise Turbo C TOOLS	129	99
Blaise C TOOLS PLUS	175	135
C Food Smorgasbord *by Lattice*	150	109
C Utility Library *by Essential, 300 functions*	185	119
Greenleaf Functions *by Greenleaf Software*	185	139
COBOL LANGUAGE		
RM/COBOL...*see Ryan-McFarland Prod.*		
Microsoft COBOL Compiler	700	499
Microsoft COBOL Compiler *for XENIX*	995	795
Micro Focus COBOL...*see Micro Focus Prod.*		
dBASE SUPPORT		
BRIEF/dBRIEF...*Brief for DBASE III*	275	Call
CLIPPER...*from Nantucket*	695	375
McMAX...*dBASE for MAC from Nantucket*	295	Call
dBx..*dBASE to C Translator by DESKTOP AI*	350	299
with Library Source Code	550	469
with Full Source Code	1500	1282
dBC...*from Lattice...maintains DBASE files*	250	195
with source	500	390
dBC III Plus...*supports multi-user DBASE*	750	595
with source	1500	1185
DEVELOPMENT TOOLS		
BASTOC *by JMI, convert BASIC to C*	495	399
BASIC-C *BASIC's functions added to C*	175	139
Report Option *Softcraft Btrieve Report Gen.*	145	128
Xtrieve *Softcraft Query Utility for Btrieve*	245	220
Code Sifter *Profiler by David Smith*	119	89
Dan Bricklin's Demo Program *Prototyper*	75	69
LMK *from Lattice, "make" like UNIX*	195	149
Microsoft Window Development Toolkit	500	365
ESSENTIAL PRODUCTS		
C Utility Library	185	119
Essential Graphics	250	183
Essential Comm Library	185	125
with Breakout Debugger	250	189
FILE MANAGERS		
Btrieve *by Softcraft, no royalties*	250	195
Btrieve Network *by Softcraft*	595	465
C-Tree *by FairCom - no royalties, source*	395	329
R-Tree *by FairCom-Report Generatcr*	295	245
C-Tree & R-Tree Combo *by FairCom*	650	541
dbVista *single user DBMS by Raima*	195	139
dbVista *multi-user DBMS*	495	399
Opt-Tech Sort *Can sort Btrieve files*	149	105
FORTRAN LANGUAGE		
RM/FORTRAN *by Ryan McFarland*	595	499
FORTRAN Libraries...*by Alpha Computer*	70	45
Microsoft FORTRAN *Links w/Microsoft C*	450	281
Microsoft FORTRAN *for XENIX*	695	546
Scientific Subroutine Package *by Alpha*	295	239
GRAPHICS		
Essential Graphics *Essential, no royalties*	250	183
GSS Graphics Development Toolkit	495	375
GSS Kernel System *by Graphic Software*	495	375
GSS Metafile Interpreter	295	235
Halo *by Media Cybernetics*	300	219
with **Dr. Halo II**	440	299
Halo for Microsoft *includes all fonts*	595	434
MICRO FOCUS PRODUCTS		
Micro Focus Level II COBOL *w/Animator*	495	395
Level II COBOL	349	279
Level II Animator	195	155
Micro Focus Personal COBOL	149	99
Forms-2	295	235
MODULA-2 LANGUAGE		
MODULA-2 Apprentice Pkg *by LOGITECH*	99	79

	LIST	US
MODULA-2 Magic Pkg *by LOGITECH*	99	79
MODULA-2 ROM Pkg & Cross RT Debugger	299	239
MODULA-2 Window Pkg *by LOGITECH*	49	39
MODULA-2 Wizard's Pkg *by LOGITECH*	199	159
OTHER LANGUAGES & UTILITIES		
Source Print...*source code formatter*	75	60
Tree Diagrammer..*source code diagrammer*	55	45
Help/Control *by MDS...123 style Help*	125	109
Microsoft MuMath *includes MuSimp*	300	199
Microsoft Pascal Compiler *Links w/M'soft C.*	300	199
Microsoft Pascal Compiler *for XENIX*	695	546
Turbo Power Tools+ *by Blaise*	100	67
Advantage C++ *by Lifeboat Assoc.*	495	435
PHOENIX PRODUCTS		
PASM86 *Macro Assembler*	195	138
PDisk *Phoenix's new disk manager*	195	138
Pfantasy Pac *six products...New Price*	995	655
PFinish *EXE performance analyzer*	395	278
Pfix86 Plus *Symbolic Debugger*	395	259
PforCe *vast library*	395	235
PforCe++...*Function Library for C++*	395	278
Plink86 Plus *Utilizes memory for overlays*	495	326
Pmaker *like UNIX "make"*	125	89
Pmate *with Macros*	195	138
Pre-C *UNIX "lint"-alike*	295	195
PTel *Binary File Communicator*	195	138
POLYTRON PRODUCTS		
PVCS Corporate...*Source Code Control Syst.*	395	309
PVCS Personal	149	109
PVCS Network	Call	Call
PolyMake *Complete Make Utility*	149	109
PolyLibrarian *Library Manager*	99	73
PolyLibrarian II *Library Manaer*	149	109
PolyShell *UNIX-like Command Shell*	149	109
PolyXREF *Complete Cross Ref Utility*	219	169
PolyXREF *One language only*	129	99
PolyBoost *The Software Accelerator*	80	64
PolyDesk III *3rd Generation Desktop Org*	99	73
PolyDesk III *Add On Tools*	Call	Call
RYAN-McFARLAND PRODUCTS		
RM/FORTRAN...*2.4 New*	595	499
RM/FORTRAN...*UNIX or XENIX*	750	599
RM/COBOL...*DOS*	950	799
RM/COBOL...*UNIX or XENIX*	1250	999
RM/COBOL Run Time	250	199
RM/COBOL 85...*ANSI 85 COBOL*	1250	995
RM/COBOL 85 RUN TIME	300	249
RM/SCREEN...*for COBOL 85*	395	335
RM/NET +5...*COBOL & COBOL 85 Network*	300	249
SCREEN DESIGN		
Curses *by Lattice, UNIX screen designer*	125	99
with Source	250	199
Greenleaf Data Windows...*New*	225	169
with source	395	297
Panel Plus *by Round Hill, no royalties..New*	495	395
View Manager for C *by Blaise*	275	199
Vitamin C *by Creative Programming*	225	198
VC Screen *by Creative Programming*	100	81
Windows for C *Vermont Creative Software*	245	216
Windows for Data *includes Windows for C*	395	315
ZView *Data Management Consultants*	245	175
TEXT EDITORS		
Brief *from Solution Systems*	195	Call
Condor Editor *by Condor*	130	118
Edix *by Emerging Tech...Multi-screen*	195	159
Epsilon *by Lugaru Software, like EMACS*	195	149
FirsTime *by Spruce Technology, C syntax*	295	229
Kedit *by Mansfield, similar to Xedit*	125	99
LSE, the Lattice Screen Editor *Multi Wind.*	125	100
Vedit *by Compuview*	150	99
Vedit Plus *by Compuview*	185	129

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PC BRAND™ SPEAKS YOUR LANGUAGE

CLIPPER *From Nantucket*

Compile dBASE for Speed, Protection

Clipper™ turns lumbering dBASE® into a speed dMON with benefits bobbing in its wake: your source code is submerged from public view, you can distribute your compiled application without royalties, and your customers don't even need copies of dBASE! The Spring '87 Clipper offers index files compatible with dBase III Plus, and networking capabilities to run compiled programs on major networks supporting DOS 3.1 with no restrictions on number of users. Clipper offers arrays, menu-building commands, user-defined functions, context-sensitive help techniques for applications, a debugger, and it supports Expanded Memory. *It goes* well beyond dBASE with 1,024 fields per data base and 2,048 active memory variables.

Clipper has the power to save and restore multiple screens to and from memory variables. You can also create overlays, call object modules compiled in other languages, and create function libraries to link with your applications. Power and flexibility make it the #1 dBASE compiler. List: **$695**, PC Brand: **$375**.

dBASE AT THE SPEED OF C

dBx Translates dBASE Applications to C

You dBASE™ programmers know what an expressive and readable language dBASE is. It's a very comfortable development environment. But the price is debased performance. Even compiled dBASE doesn't offer the speed that some users require these days. The kind of speed offered by software written in the C language. The answer is dBx™.

dBx translates dBASE to C. It offers you a major competitive advantage over the next dBASE programmer: Keep writing in dBASE. Take every application all the way to completion. Then use dBx to translate them top to bottom to C!

Other advantages: C is portable, even to other operating systems like UNIX/Xenix™. To the Macintosh or Amiga. dBx gives your applications a passport to places dBASE cannot go.

Has its own file manager for single user, but links to major C file managers—c-tree and dBC—for compatibility with dBASE files or multi-user support. We have everything you'll need, including good advice.

	List:	PC Brand:
dBx	**$ 350**	**$ 299**
with Library Source	**$ 550**	**$ 469**
with Full Source Code	**$1500**	**$1282**

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We refund the purchase price of any product returned within 30 days in entirely resalable condition. **You can even try out many programs themselves.** Ask your salesperson for details. There's just nothing stopping your buying from PC Brand.

C-WORTHY INTERFACE LIBRARY

NEW VERSION!

The C-Worthy™ Interface Library wraps an entire user interface around your application. Its full power can be summoned by only a few high level calls. Sound exaggerated? A single function call can set up a complete text editor in a screen window. Recently acquired by Solution System, over 600 pages of Documentation, Turbo and Quick C version and a complete Interface Library have been added.

- High level calls pop menus and scrollable choice lists to the screen, restoring the background when dismissed.
- Windowing facilities open portholes of up to screen size for viewing virtual screens larger than the physical screen.
- Full context-sensitive help screen management takes over these chores and error messages. Automatic routines interrupt with pageable text windows explaining what to do next.

Novell found it "played a key role and accelerated development" in making its NetWare™ utilities easier for users. Ingenious demo: call for it.

Ask for:	List:	PC Brand:
C-Worthy	**$195**	**Call**
with Forms Library	**$295**	**Call**

dBC *Identical dBASE III Plus Files Using C*

dBC™ is a series of C libraries from Lattice which creates, accesses and updates files identical to those of dBASE itself. So dBASE can read and update the files too.

What for? It means both C and dBASE applications can operate on the same data bases interchangably. It means C programmers can interface with the big market of dBASE users out there, yet side-step the dBASE language. It means dBASE applications can now be linked to the universe of C libraries and tools to add windows, graphics, statistical analysis, all the things dBASE cannot do. It means the speed and power of C to impress clients accustomed to dBASE!

dBC's functions parallel all dBASE's file handling commands, many decomposed to permit direct data manipulation. Our versions of dBC mimic file formats for dBASE II and III and now dBASE III Plus makes your programs network ready!... as many stations as a network allows. Hands-off mode handles record and file locking and unlocking automatically. Close in functions give you direct lock/unlock control.

Supports all four memory models. dBASE II, III...List: **$250**, Ours: **$195**. dBASE III Plus...List: **$750**, Ours: **$595**. *Pay double and you get source too!*

McMAX *From Nantucket*

Like dBASE for the Macintosh

McMax™ is like running dBASE on the Macintosh. It combines an easy-to-use menu-driven ASSIST mode using the Mac interface, an interactive command mode like dBASE at the dot prompt, and an application programming language fully compatible with dBase III. It gives you the power to create dBASE language applications on the Macintosh and transfer back and forth to the IBM® world. McMax accommodates up to 16 million records, 32,000 characters per record, 255 characters per field, and up to 32 files open concurrently. No copy protection. List: **$295**, PC Brand: **Call**.

SUPER SOURCE

Aldebaran's Source Print

Author Alan Simpson writes "the best overall debugging technique is to draw lines to connect all the IF and DO WHILEs etc. with their ENDIFs and ENDDOs. Then use a pencil to"—Well, thanks, Alan, but we'll use Source Print instead. It draws those vertical lines to connect the beginnings and endings of structure in a vivid display of your program's organization. It can print your programs with page numbers, headings, line numbers, indent automatically, throw in a table of contents and cross-reference index. "Occasionally a utility comes along that makes a programmer's life much easier. Source Print is such a program" says *PC Magazine*. List: **$75, Ours: $60.**

...add Tree Diagrammer

Tree Diagrammer prints an organization chart of your program's structure showing the hierarchy of function, procedure, and subroutine calls. Shows at a glance what routines call each other for clearer debugging. Every shop should have this important documentation tool. List: **$55**, Ours: **$45.**

BASTOC *BASIC Into C*

For a trifling price, BASTOC™ moves truckloads of BASIC code over to C. It's a translator which takes in Microsoft Extended BASIC and emits pure K&R C for Microsoft or Lattice. Structures even convoluted BASIC code. Optimized to dramatically reduce execution time. Dynamic string allocation ends BASIC's catatonic halts for garbage collection. Huge worksaver. List: **$495**, Us: **$399**.

BTRIEVE *B-tree File Manager Plus Add Ons*

If networks are on your horizon, betting your future on Btrieve as the one file manager for your C, Pascal, BASIC, and COBOL projects looks like a smart move. Reason? Novell bought Btrieve's creator.

Btrieve's function library takes complete charge of all file creation, indexing, reading, writing, insertion, deletion, space recapture, forward and backward searching. Finds any key in a million in four or less accesses. Files may have up to 24 indexes; fixed record length to 4090 characters; variable length to 64k; indexes up to 255 characters; files of 4 billion bytes.

List: **$245**, Us: **$195**. Network Version List: **$595**, Ours Only: **$465**. Ask about Xtrieve for Btrieve file inquiry, Rtrieve for report writing. For any network that supports the MS-DOS 3.1 file sharing function.

PANEL PLUS

Library Source Code Gives It Complete Portability

There are no end of tools for screen design and data entry, but none quite like Panel Plus. Design a screen under program control, use Panel's utility to "run" and test it field by field, then pass it to Panel's code generator which delivers C source code. Options style the code to your compiler's liking, and you can of course do what you like to the source afterward. The code calls Panel Plus's function library, but now *the library comes in source*, so everything produced is highly portable. Not like other screen managers delivered as object libraries and which leave *you* to write the detailed code.

Panel Plus will operate in graphics mode via interfaces to graphics products it supports and can utilize the EGA's 43-line screen. Low-level I/O functions adapt it to various keyboards, screens, operating systems.

Panel's newest incarnation has every imaginable feature. A single screen design can have 1000 fields stacked as visual overlays up to 127 levels deep or as pop-ups. Groups of fields can be moved between levels. Screens can be output as compilable code or stored on disk for loading at run-time. Each field can be boxed, colored, multi-row, word-wrapped, and scrolled horizontally and vertically if larger than its on-screen view aperture. It can be assigned its own help and error message, can be told to accept certain characters, or to match a picture, and to check data after entry—proper dates, number ranges, etc.—using Panel's or your own validation routines. You can add your routines to Panel's test utility because even it comes as source. Fields are accessed in any order and control reverts to your application program after each field for choice of action.

For past Panelists, the new version has smaller and faster field and screen functions, tighter granularity, and an enhanced, reworked library. Major tool for the serious developer. List: **$495**, PC Brand: **$395**.

POLYTRON VERSION CONTROL

Source Code Control for Any Language

PVCS allows programmers, project managers, librarians and system administrators to control the proliferation of revisions and versions of source code in software systems. Independent programmers, the leading software publishers and LAN companies, and hundreds of Fortune 1000 companies rely on PVCS to store and retrieve multiple revisions of text. It maintains a complete history of revisions as an "audit trail", generates status reports, and uses intelligent "difference detection" to minimize disk space for each new version.

On Corporate and Network PVCS simultaneous changes to a module are merged into a single new version. If changes conflict, the user is notified. The "Logfiles" used to track changes are interchangeable between any PVCS product.

Corporate PVCS is for multiple programmers. It includes "branching" to maintain code when programs evolve on multiple paths. Personal PVCS offers most of the power and flexibility of corporate PVCS, but excludes multiple programmer features. Network PVCS is the Corporate version for LANs. File locking and security levels can be tailored to each project.

PolyMake Still using a prehistoric Make? Step up to PolyMake, the most popular and powerful Make utility. Most flexible macros of any Make. Now integrated with PVCS and Poly-Librarian for faster performance and precise configuration management.

Ask for:	List	PC Brand:
Personal PVCS	**$149**	**$109**
Corporate PVCS	**$395**	**$309**
Network PVCS	**Call**	**Call**
PolyMake	**$149**	**$109**

Payment: We honor MasterCard, Visa, American Express (no surcharge), checks in advance, or funds wired to PC Brand, c/o Chemical Bank, 126 East 86 St., New York, Account 034-016058. COD (U.S. only) for cash, money order, certified check (no fee). NY State, add sales tax. Purchase orders accepted from larger corporations and institutions at our discretion if you agree to net 30 days plus 2% a month late penalty thereafter.

Shipping & Handling: U.S.: UPS Surface: 1st product $6, each add'l $3. UPS 2nd Day Air: 1st product $10, each add'l $4.50. UPS Next Day Air or Federal Express 1-2 Day Air: 1st product $18, each add'l $6. FedEx Next Day 10 AM: 1st product $28, each add'l $7. International: Charges vary by destination and carrier. $10 per shipping container for export forms. Air parcel post at your risk beyond collected insurable amount.

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CIRCLE NO. 233 ON READER SERVICE CARD

Some of the best dBASE III PLUS

More than 80 books and technical journals have been written exclusively about dBASE.

For years, just about every PC magazine, software expert and computer dealer have been telling you that dBASE III PLUS™ is the most powerful DBMS. That it gives serious programmers the most versatile set of tools. And helps new users develop sophisticated applications.

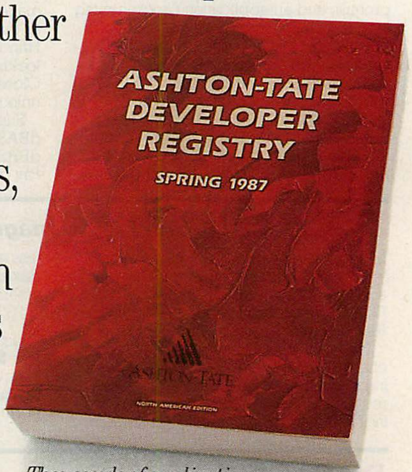
That's nice, but frankly, it seems a bit limited to us.

Because there are a lot of reasons to buy dBASE III PLUS that have nothing to do with power.

First of all, we have over 1.5 million customers. That clearly makes us the industry standard.

And there are over 80 magazines, books and technical journals to help you take maximum advantage of all the capability built into dBASE.®

The Ashton-Tate® Developer's Registry is another good reason.



Thousands of applications are available for dBASE. So chances are you won't have to start from scratch.

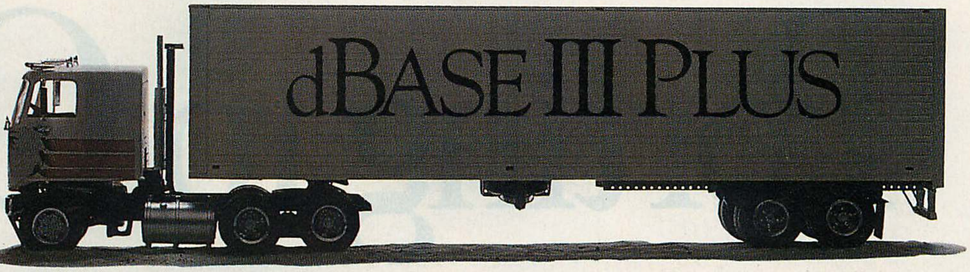
With over a thousand pages, this book gives you information on applications in every area from 12 meter yacht racing to hog farming. So there's no need to create an application from the ground up. Unless you want to.

There's also our LAN Pack, which

We have a much larger support group than any other database company. When you need help, you're never alone.

reasons to buy aren't in the box.

gives you a simple, cost-effective way to share the power of dBASE III PLUS with other users.



dBASE has shipped over 1.5 million copies to customers, which makes it the industry standard by a huge margin.

Finally, we've used our considerable resources to create the largest support group of any DBMS company. With 207 full-time support people, we offer a full range of support service for everyone. From 90-day free phone support for new users to remote on-line diagnostics for advanced users. We also give you the most thorough, easy-to-follow documentation. Along with the best customer training.

So if you're looking for the database that can do the most for your business, take a good look in the box. And a good look what's behind it.

For more information, or the dealer nearest you, just call (800) 437-4329, Extension 3327.

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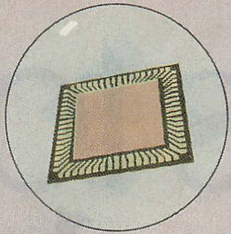
CIRCLE NO. 231 ON READER SERVICE CARD



An inside look reveals how one company rapidly converted a complex data manager from DOS to the OS/2 environment.

Porting to OS/2

STEVEN ARMBRUST

When Microrim, Inc., became a beta site for IBM's new Operating System/2 (OS/2) in late 1986, Microrim chairman and founder Wayne Erickson knew immediately what he and his staff had to do. Not only did they have to convert R:BASE System V, Microrim's largest and most complex database manager, to run under OS/2, but the job had to be done in time to demonstrate a working product when IBM officially announced OS/2. At the time, no one knew how soon the announcement would occur (it came just six months later).

Microrim—located in the same Redmond, Washington, neighborhood as OS/2's developer, Microsoft—is a forerunner in converting to OS/2. The company internally committed to the OS/2 conversion of R:BASE System V in late 1986 and completed it in time to demonstrate the product at IBM's formal announcement of OS/2 on April 2 of this year in Miami.

"We knew the job would be big, because our program is big," Erickson said. "But with all the enhancements we wanted to make to our product, and because of the endorsements of IBM and Microsoft, we felt we couldn't ignore OS/2."

Microrim is counting on OS/2 to be a big boon in the constant battles the company must wage with competitors, most notably Ashton-Tate of dBASE fame, to add new features and otherwise improve its products. For R:BASE System V, which already strains at the 640KB memory bounds that are available under DOS, OS/2's 16MB of memory will open the door to new features. It will also improve system performance by eliminating the need for cumbersome overlays used to squeeze numerous program elements into the overflowing 640KB memory bag. As it is now, heavy use of overlays as required by R:BASE under DOS diminishes the product's performance even on an AT-class computer.

Microrim approached the OS/2 conversion systematically and found it relatively uncomplicated, said company managers, largely because R:BASE System V (like all Microrim products) is modularly designed, thus nullifying the need for complex and interconnecting adjustments during conversions. The converted R:BASE System V is capable of running under OS/2 and using OS/2's expanded memory and some multitasking capabilities with other OS/2 applications; however, it does not yet fully tap all OS/2 features, such as multithreading and the operational doors that capability can open.

The converted R:BASE System V is not yet on the market and prices are unavailable. Microrim plans to release the product when IBM releases OS/2; meanwhile, Microrim engineers are working to enhance it with features arising out of capabilities specific to OS/2. According to Microrim, R:BASE System V will remain available in DOS for users who do not want to convert their operations to OS/2.

PLANNING THE CONVERSION

As Microrim managers sat down late in 1986 to plan for the OS/2 conversion they were faced with several questions. How could Microrim engineers, who were just learning OS/2 themselves, convert an application as large and complex as R:BASE System V to the new operating system? What was the best way to proceed to optimize company resources? Should Microrim create a family application (one that could run under both DOS and OS/2 but that could not take full advantage of new OS/2 features such as extended memory and multitasking) or a separate application for OS/2 that would allow R:BASE System V to take advantage of the full extended OS/2 features? How should they proceed with the inevitable language conversion (from FORTRAN to C), and should they rewrite the program by hand or use an automatic language translator? Finally, how could Microrim accomplish the conversion in time to meet the fast-approaching (but still unknown) IBM deadline?

The company. From all observations, Microrim and its R:BASE System V prod-

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Microrim's OS/2 conversion of R:BASE System V was spearheaded by company chairman and founder Wayne Erickson (standing), senior vice president of research and development Fred Gray (right), and computer systems engineer Alan Lindsay. The company got its start using the Heath H88 computer shown in the photo to develop its first microcomputer product, called Microrim. That product evolved into R:BASE System V from a mainframe database product.

uct were ahead of the conversion game from the start. First, Microrim had previous experience converting products to new operating systems. Second, the modular nature of R:BASE System V allowed for the conversion to be done by making some rather simple, segregated changes as opposed to making complex and extensive modifications.

Microrim was formed by Erickson in November 1981 to develop a microcomputer version of a mainframe database product called RIM (for relational information management) that he had created for NASA in 1978 to validate relational database technology. RIM was subsequently made available on 22 different mainframes, including those made by Control Data, Cray, Burroughs, DEC, and Prime. Microrim's first product—the minicomputer version of RIM—was named for the company and released for use on CP/M-based machines in July 1982.

Later that year, the company did two ports—one to IBM's DOS and one to Convergent Technologies' CTOS. In October 1983, Microrim did a major revision of the product and renamed it R:BASE 4000, followed by another major upgrade called R:BASE 5000 in April 1985 (reviewed in "A Data Manager with Kernel Code Generation," Steven Armbrust and Ted Forgeron, September 1985, p. 82) and, ultimately, the release of the current product, R:BASE System V, in July 1986. In the six years since it was founded, Microrim has grown from a company with seven people to one with 135 employees.

Decisions. Although Microrim management remains committed in the long term to enhancing R:BASE System V so that it can eventually use all applicable OS/2 features, time constraints forced the company to take a conservative approach in the beginning. Instead of redesigning the product to add the

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new operating-system-supported features, Microrim initially decided to make a direct port of the existing product in order to meet the tight schedule. With this port, R:BASE System V immediately takes advantage of OS/2's larger memory space and ability to run concurrently with other OS/2 applications; however, it still needs further enhancements to take advantage of all the other features of OS/2.

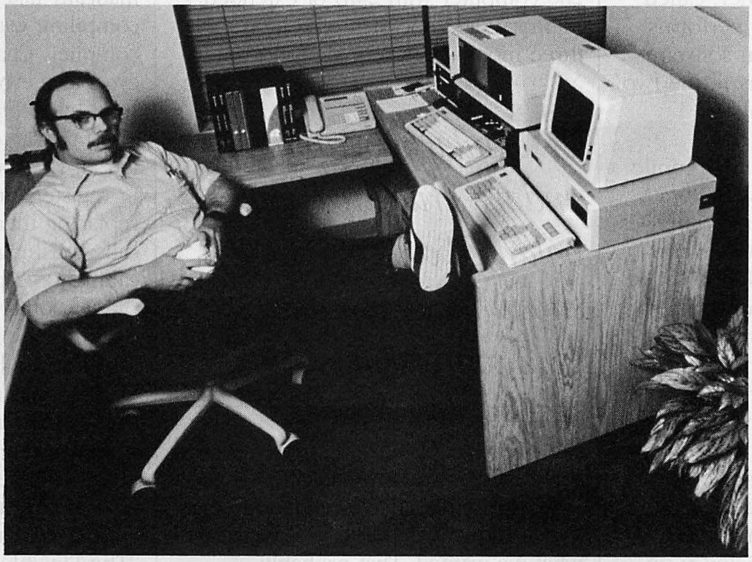
Further, Microrim decided to create a separate application for OS/2 rather than a family application; whereas a family application would have the advantage of running under both OS/2 and DOS (thus minimizing the number of different packages Microrim would have to stock, support, and maintain), it would be limited to using only OS/2 features that have counterparts under DOS. Despite the advantages of a family application, however, Microrim managers decided without hesitation to develop separate applications for OS/2 and DOS. Their goal was to create a product that does not limit OS/2 users to those features of OS/2 that are also available under DOS.

"We did not want to be unnecessarily constrained by the memory limitations of DOS, so we chose to go with two versions of the product, one for DOS and one for OS/2," explained Alan Lindsay, Microrim's computer systems engineer who performed the OS/2 conversion. Lindsay expects other developers of large applications to make the same choice, leaving the family-application approach primarily for utility programs, such as compilers, that do not require internal multitasking or large memory space.

Finally, Microrim needed a strong configuration control system. (For a review of six such products, see "Tracking Code Modules," Jim Vallino, September 1987, p. 50.) This would allow its staff both to upgrade the company's products individually and to maintain a common database for making generic changes simultaneously to all products. Configuration control is important because Microrim intends to sustain updated DOS and OS/2 versions of all its products, including Clout (a user query interface) and Program Interface (a programming tool).

After examining several commercial configuration control systems, however, Microrim decided to build its own system in R:BASE System V because it could not find one on the market to meet its specific needs.

The strategy. Microrim approached the OS/2 conversion of R:BASE System V in two stages. The first was a language conversion (most of R:BASE System V was written in FORTRAN, but in order to use OS/2 as it currently exists, the program had to be translated to C). The second phase was the actual conversion from DOS to OS/2.



Microrim engineer Alan Lindsay used a Compaq Portable 286 (rear) with 2MB of extended memory to isolate and change operating-system calls and test and debug the new system. He used the IBM PC/AT (foreground) to access programs in DOS for conversion to OS/2.

THE SWITCH TO C

When R:BASE was developed, FORTRAN was the most portable language available and Microrim engineers knew it well—largely because R:BASE's RIM ancestor was written in FORTRAN. Thus, the original R:BASE was in FORTRAN, but enhancements to later R:BASE versions were written in C. Going into the OS/2 conversion, R:BASE System V still contained 70 to 75 percent FORTRAN code, 10 to 20 percent C code, and the remainder was in assembly language.

No FORTRAN compilers are yet available for OS/2, so Microrim had to convert R:BASE before it could start the OS/2 conversion. Such a language conversion had been on the minds of Microrim developers for some time, but they were reluctant to undertake this major project for its own sake. As Erickson explained, "We feared that the entire staff would spend two years on a conversion and the product would do nothing different from the current product." Nonetheless, Microrim engineers knew the language switch was inevitable—with or without OS/2—in order to keep R:BASE System V competitive in the marketplace, so the company started the wheels for C conversion in motion last fall. It accelerated the conversion effort a few months later when OS/2 became a reality.

The conversion to C, including hand-tweaking, required four to five people over a period of three months. To save time, Microrim engineers used Rapidtech Systems, Inc.'s FORTRIX-C, a language translator that reads source code in one programming language and produces source code in another language as output. Although the code produced by mechanical translation is not as efficient as code written by hand, the conversion package can produce an initial draft in the target language in a much shorter time. Engineer Lindsay explained that even when the translator's output required further refining by customized conversion routines or hand-tweaking, using a translator significantly reduced the time and effort of producing a finished program in the target language.

A certain amount of post-processing of the translator output was inevitable because FORTRIX-C, as a general-purpose conversion program, could not be expected to meet all of the specific requirements of a program as complicated as R:BASE System V. For example, FORTRIX-C converts a FORTRAN COMMON block into a series of pointers to an array and generates code to initialize these pointers at every entry to a function. Microrim engineers therefore had to write their own routines to convert COMMON blocks to C structures that require no address manipulation at runtime.

In addition, FORTRIX-C automatically generates all integers as long integers in C, but Microrim wanted them to be short integers; therefore, this had to be done manually. Finally, because FORTRIX-produced code is less efficient than handwritten code, Microrim engineers reviewed the FORTRIX-generated

code when time allowed and manually cut out extraneous statements, reducing the size of the source code by approximately one-half.

The engineers confronted an interesting problem during the language conversion; when a math coprocessor was not present, floating-point operations were much slower in C than in FORTRAN. This was because Microsoft's FORTRAN and C compilers use two kinds of floating-point libraries. The standard library uses a math coprocessor if it is present or emulates it in software if it is not. The other, called the Alt Math library, always performs floating-point calculations in software. The efficiency of emulations in the two libraries is not always equal.

In version 3.3 of Microsoft FORTRAN, which was used to compile the FORTRAN code of R:BASE System V, the emulating routines in both libraries performed equally as fast. When the converted code was compiled with the Microsoft C 4.0 compiler, however, the emulation routines in the standard library were considerably slower than those in the Alt Math library. The Microsoft FORTRAN 4.0 compiler experienced the same problem with emulated floating-point routines.

Microrim considered using the Alt Math routines to achieve increased floating-point execution efficiency on systems without a math coprocessor (still the majority of PC systems). But this had two disadvantages. First, software routines in the Alt Math library gained execution efficiency at the expense of numeric accuracy and error checking. Second, the performance of an Alt Math product could be improved by adding a coprocessor.

In a database manager, floating-point efficiency is significant only if real-number data exist in the database; otherwise, manipulating data files is not a compute-intensive activity, and integer arithmetic is adequate for whatever computations are required. Therefore, Microrim engineers decided to accept the slower execution efficiency of the standard math library. In return, users have increased accuracy. For applications requiring upgraded efficiency, users can add a math coprocessor.

"The [language] conversion encouraged our development staff because they found they could take advantage of the C environment and decrease the code size of the product. Plus, they had a chance to clean up routines written several years ago and make the code tidier," Microrim chairman Erickson said.

Microrim's work was far from finished once the C conversion was complete, however. It still had to convert the C code to run under OS/2.

ONE-MAN JOB

The OS/2 conversion was less involved than it might have been because Microrim earlier had decided to limit its near-term efforts to producing a functionally equivalent OS/2 version of R:BASE System V without adding all the bells and whistles. Lindsay took on the job himself, using a Compaq Portable 286 computer with 2MB of extended memory. The one-man operation took three months. "In terms of effort, it was really only about half of a conversion," he said. "There weren't any big surprises; we were able to do exactly what we wanted. That probably wouldn't have been true if we were doing more than just a straight port."

> ***Modular programming and the structured, well-balanced code of R:BASE substantially expedited the OS/2 conversion.***

Both modular programming and the structured, well-balanced code of R:BASE System V substantially expedited the OS/2 conversion. Erickson explained, "We've always tried to keep our machine- and operating-system-dependent code clearly isolated, so the number of routines we had to change for OS/2 was considerably smaller than it could have been."

Earlier conversions of Microrim products from different operating systems compelled company engineers long ago to isolate all operating-system-specific operations into a small set of procedures that other routines call whenever they need operating-system services. This set of procedures was placed into a library. Instead of making DOS calls directly, the rest of the routines in R:BASE System V called the routines in this library. As a result, the task of isolating DOS calls is easier, and fewer system-specific modules need to be rewritten.

Of approximately 2,500 total routines making up R:BASE System V, only 25 to 50 of them contained DOS calls that needed to be converted. Consequently, only about two percent of approximately 90,000 total lines of source code needed to be changed. Procedures that did not issue operating-system calls were able to function under OS/2 without change because none of them breaks rules of protected-mode operation, such as performing arithmetic on segment registers or attempting to access memory outside assigned memory space.

Any operating system functions handled by calls to standard C library routines were, for the most part, automatically taken care of simply by recompiling with the OS/2 version of the compiler. Changes were required, however, in the operating-system calls issued by assembly language routines. The majority of effort was spent isolating all DOS-style calls (placing values in registers and issuing an INT 21) and replacing them with equivalent OS/2 calls (pushing values on the stack and calling OS/2 procedures).

In some cases, the conversion could be applied at a higher level. Because of the higher-level syntax of the OS/2 applications program interface (API)—the rules for calling up OS/2 routines—some calls to assembly language routines implementing customized system interfaces were replaced with direct calls to OS/2 functions. (See "The Flexible Interface," David A. Schmitt, this issue, p. 110.)

After isolating DOS calls and determining OS/2 equivalents, Lindsay tested each of the new system calls with a small test program. By taking this approach, Lindsay could monitor system operation and determine any operating quirks, performance problems, or bugs. He was able to determine immediately whether he would need to redesign parts of the application because of differences between DOS and OS/2.

In at least one instance, Lindsay had to make some modifications. Applications that formerly wrote to DOS video memory easily wrote to the OS/2 logical video buffer, but applications that send characters to the screen one at a time experienced a significant slowdown. To improve performance, Lindsay reprogrammed the R:BASE video procedures to write a string of characters to the logical video buffer first, then to update the screen.

The extent of IBM and Microsoft contributions to the R:BASE System V conversion effort is unclear. "We had what we needed, and we got help when we needed it," Lindsay said, but he would not elaborate because of a confidentiality agreement that Microrim

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signed prior to the conversion. Neither would Lindsay describe the documentation he worked from, although it is safe to assume that the material was similar to the OS/2 Software Development Kit now available commercially.

BETTER WITH OS/2

Because the conversion went smoothly, Microrim completed its prototype OS/2 version of R:BASE System V in time for the introduction of IBM's OS/2 on April 2 in Miami. The conversion was essentially a direct port of the DOS version, but it automatically takes advantage of a couple of OS/2 features.

First, the ported program is not restricted to DOS's 640KB memory limitation. Instead of being heavily overlaid as the DOS version is, the entire program (approximately 680KB worth) is loaded into memory at once. This improves the performance of the product, and it also eliminates the development burden of having to plan an overlay structure to optimize performance.

In addition, R:BASE System V and other OS/2 applications can be multitasked or a user can invoke two copies of R:BASE simultaneously to obtain multitasking features not built into the program. For example, a user can start up one copy of the program to print out a report and start another one to enter records into the database. Because OS/2 shares code segments, the memory space required by each subsequent invocation of a program is significantly less than the first. Also, because DOS's networking features are carried over to OS/2, R:BASE System V's built-in networking capabilities enable multiple invocations of the program, as well as multiple users, to update the same database without fear of corruption.

Microrim did not find that the OS/2 version of R:BASE System V runs any slower than the DOS version. Certainly, OS/2, as a multitasking operating system, has more overhead and could, in general, be expected to run slower than a single-tasking application such as DOS. However, because Microrim was able to remove the overlays required under DOS for R:BASE System V, the company actually improved the performance of the OS/2 version.

Instead of focusing on raw speed for isolated functions (i.e., sorting), Microrim believes that users should look at total throughput over time of combined functions (sorting, printing, etc.) to determine whether an OS/2 version of an application is superior or inferior to a DOS version. "It's not how long a sort takes, but how much I can get done in an hour that's important," Fred Gray, Microrim's senior vice president of research and development, said. The multitasking features of OS/2 give database users the ability to get more done per hour.

Microrim managers remain confident that the OS/2 conversion was worthwhile and has put them in an ideal position in the marketplace. If IBM releases OS/2 immediately, Microrim could release the ported R:BASE within days. Meanwhile, they have a team of developers enhancing the product with OS/2-specific features.

The upcoming Presentation Manager, being developed by IBM and Microsoft for use with OS/2, presents another opportunity to Microrim. Although sophisticated database users might not be helped much by a graphical user interface, such as the Presentation Manager, Microrim understands that effective use of graphics can help novices pick up database concepts more easily. In addition, the ability to build graphically oriented database applications could help sophisticated

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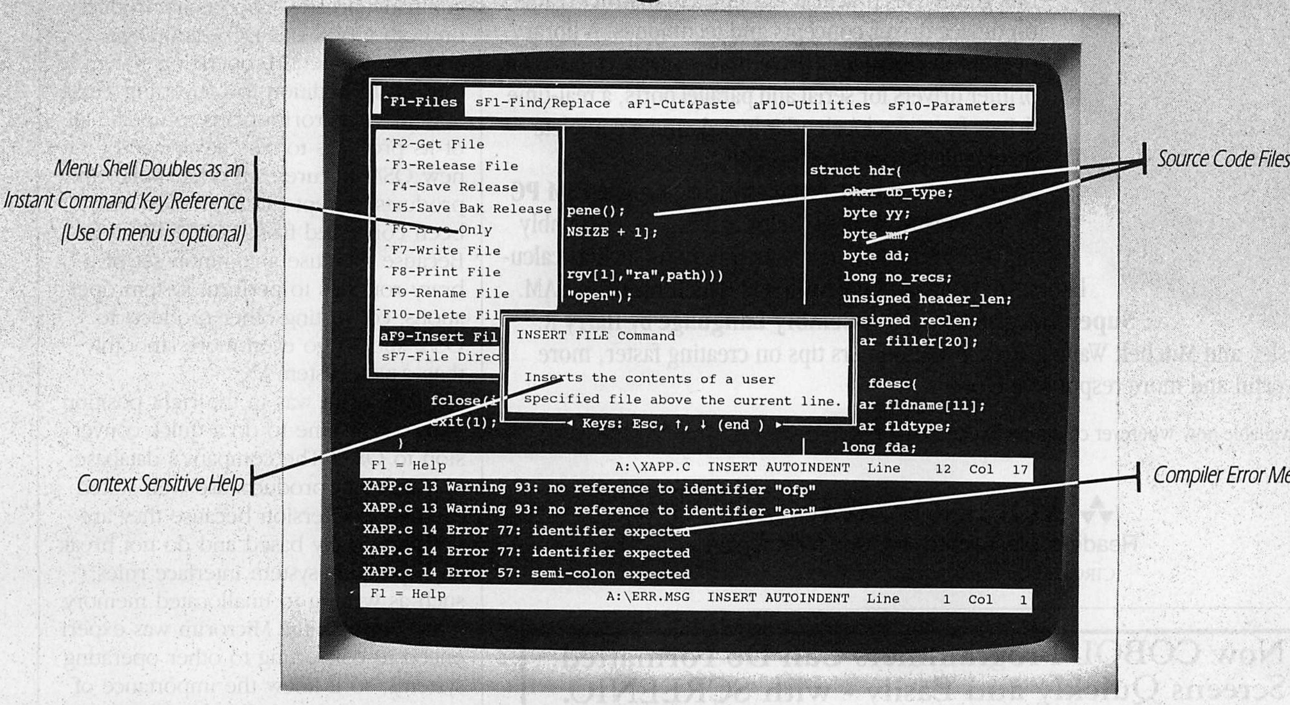

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users build better applications for novices to use. Because the release date of the Presentation Manager is uncertain, Microrim has not made firm plans about which Presentation Manager features to put in R:BASE System V.

Even in their enthusiasm to develop an OS/2-only version of R:BASE System V, Microrim officials have not deserted their DOS customers. The company already supports its products on both CTOS and DOS, and OS/2 adds another entire operating system to the list. In addition to converting R:BASE System V, Microrim plans to update all of its products to take advantage of the new OS/2 features. All other Microrim products, except Clout, already have been converted from FORTRAN to C. Because they use a common set of library routines to perform system operations, converting other products to OS/2 should go even more smoothly than R:BASE System V.

Microrim was in the right position at the right time to do a quick conversion to OS/2. The company's database management products are well suited to quick conversion because they are not graphically based and do not break any operating-system interface rules, such as writing to unallocated memory. More importantly, Microrim was experienced in converting to other operating systems, so it knew the importance of writing modular, well-behaved code.

Lindsay cautioned against expecting to convert all DOS calls to OS/2 and have them work right away. He stressed use of modular code and recommended making poorly structured DOS programs modular first, isolating operating-system calls to a few procedures. When restructured code is working correctly under DOS, operating-specific-routines can then be recoded under OS/2 and tested. By isolating operating system calls to just a few procedures, OS/2 conversion involves changing only a small set of procedures, not searching through every line of source code. "Even if you don't have modular, well-behaved code before you start converting, you will when you finish," Lindsay concluded.

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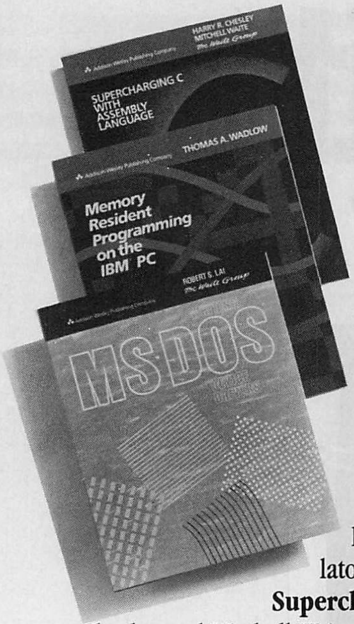

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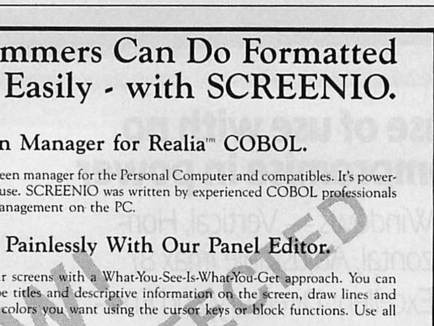

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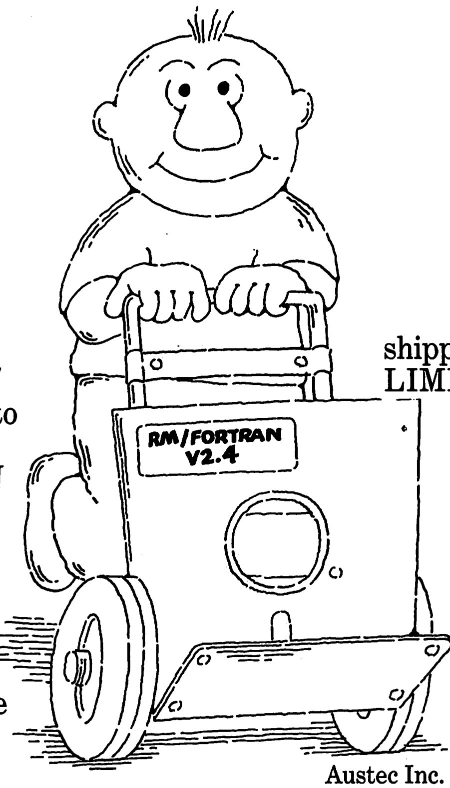

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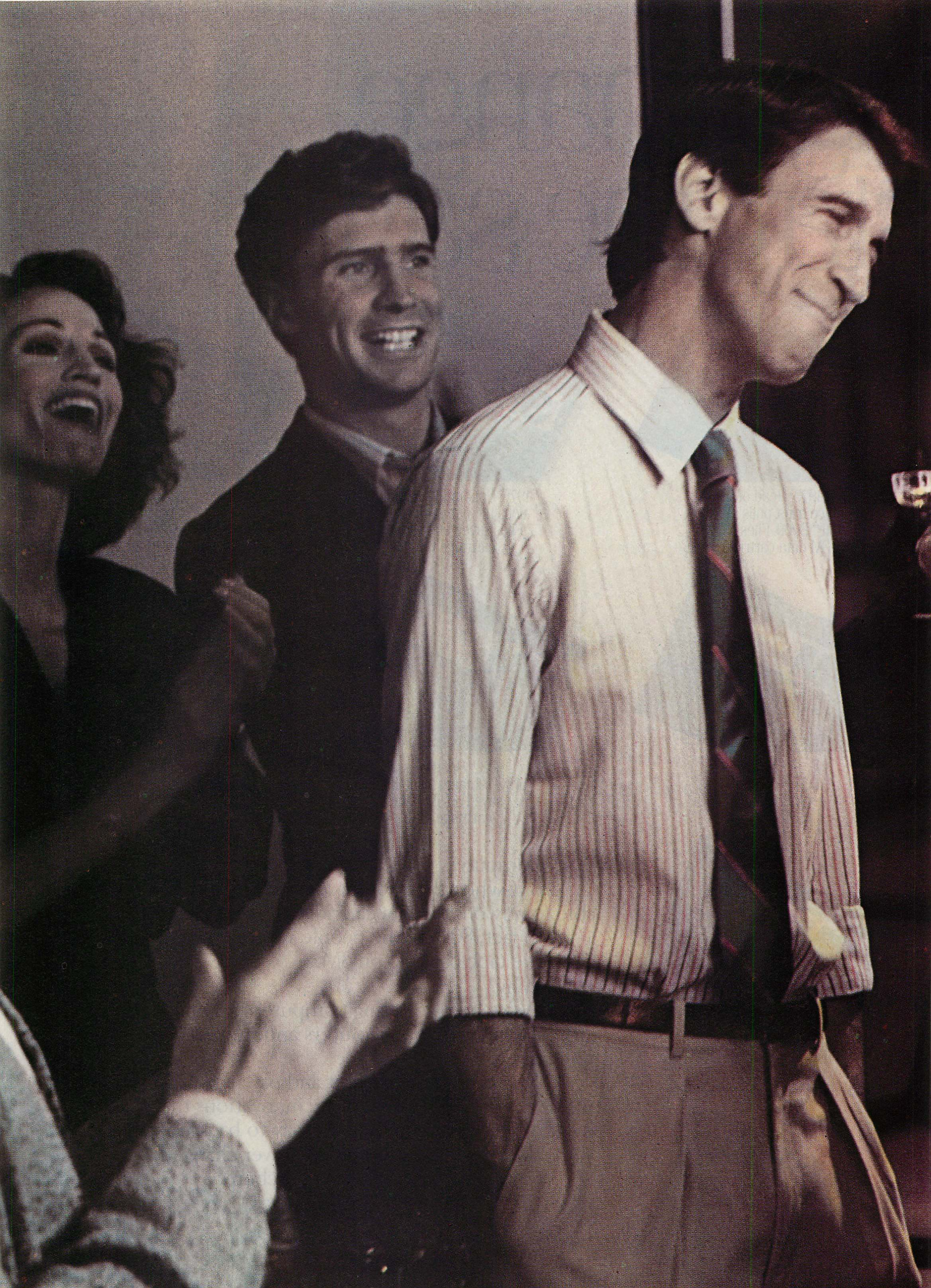

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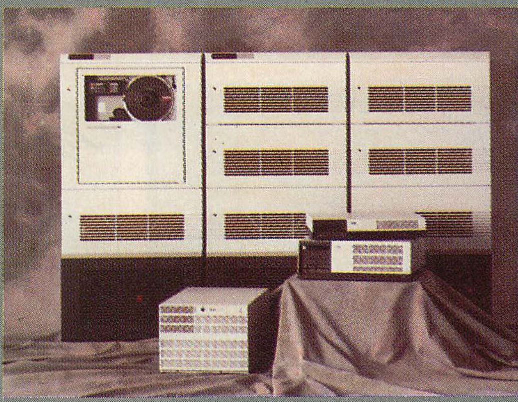

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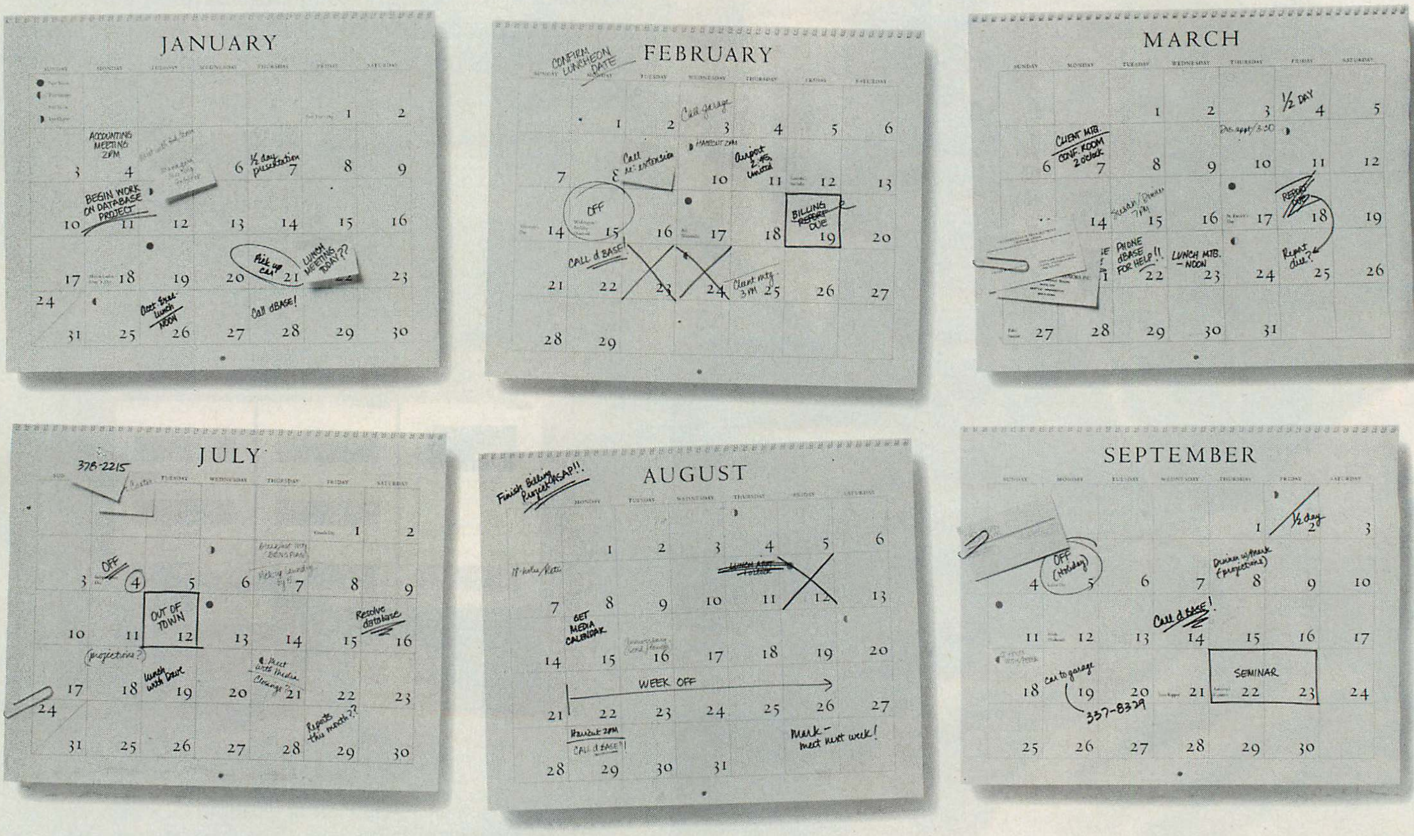

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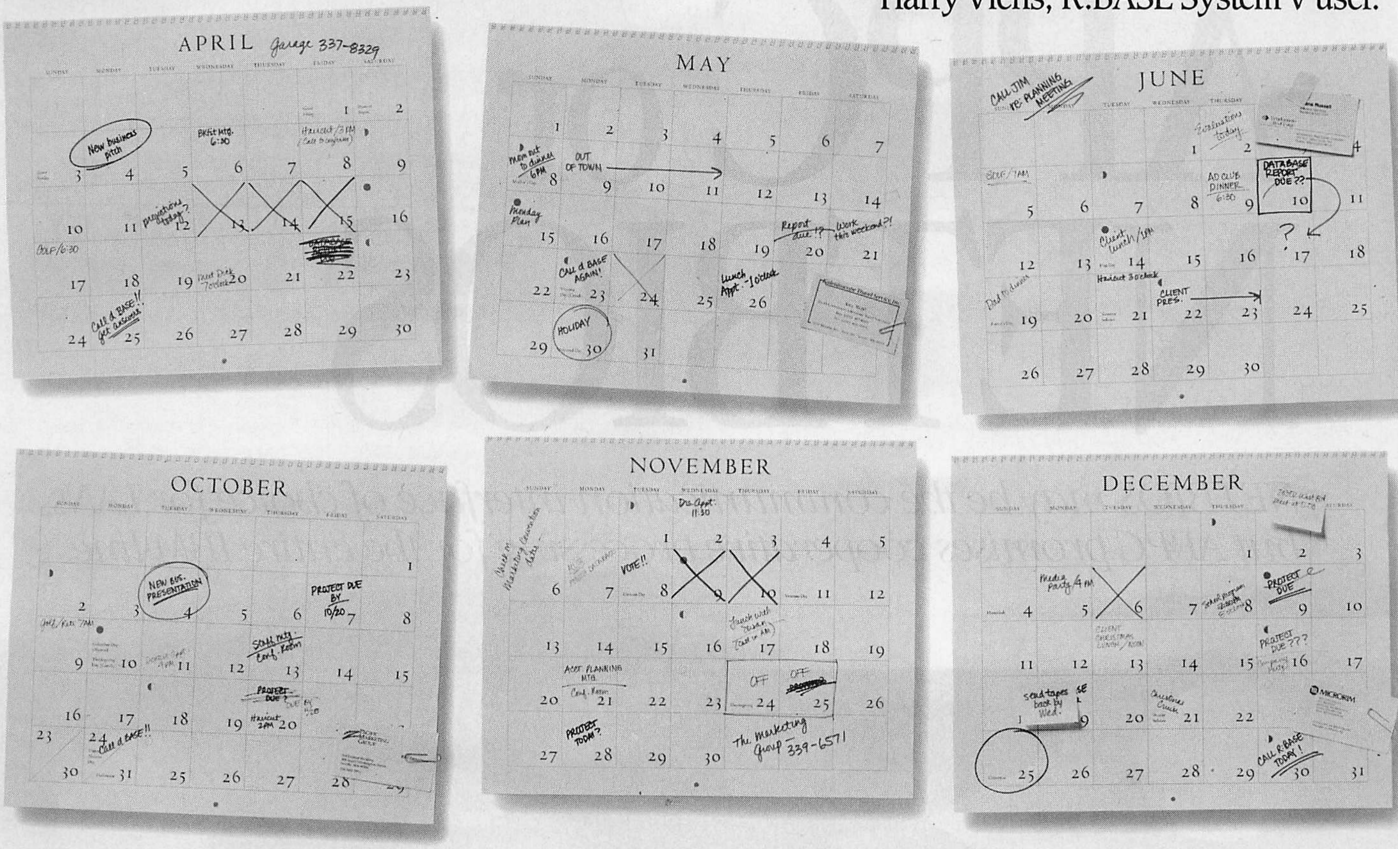
— Harry Viens, R:BASE System V user.



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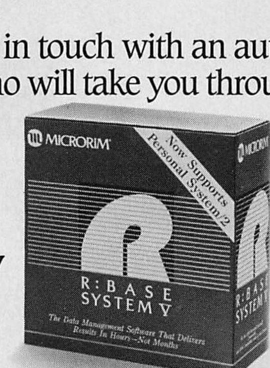

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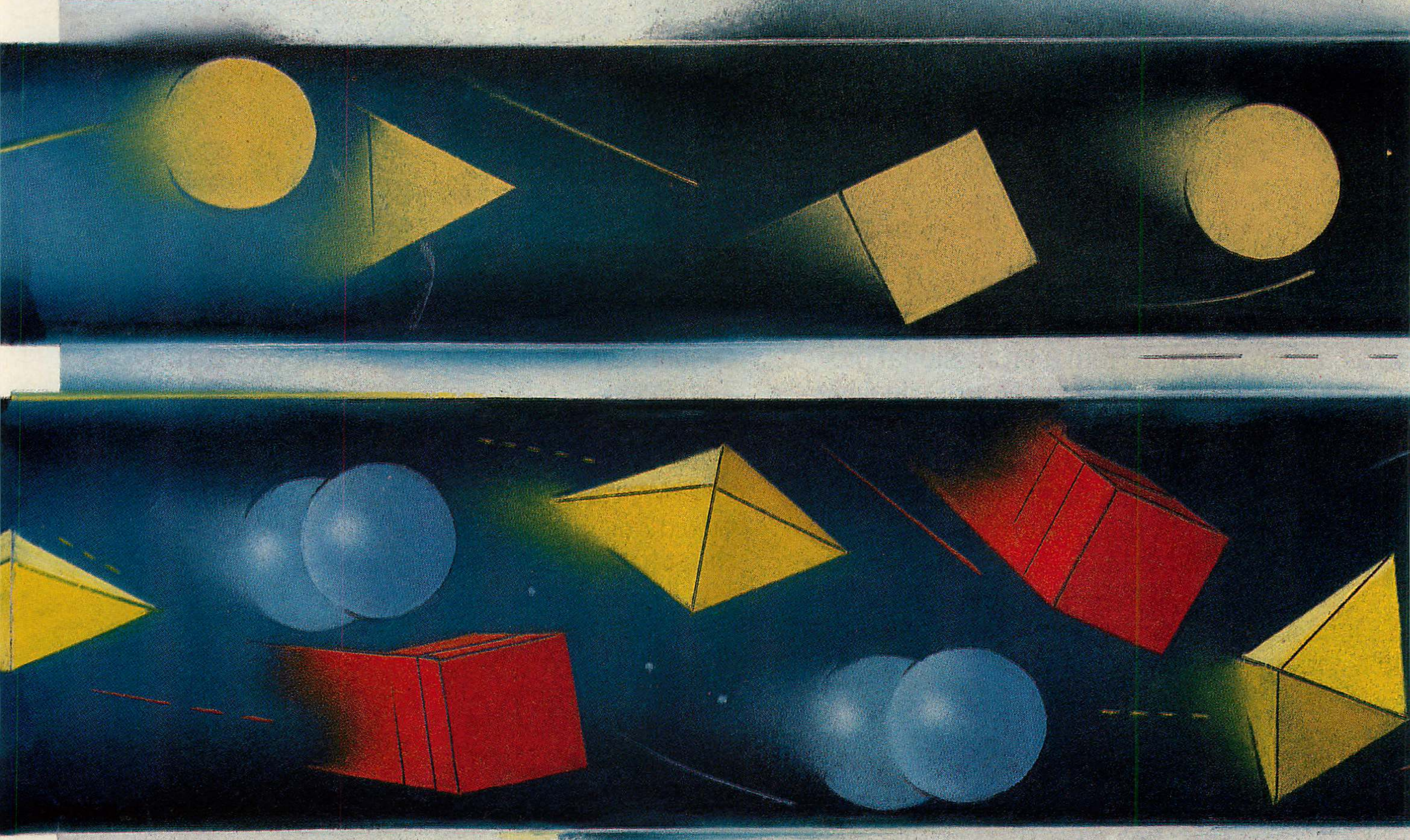
CONNECTIVITY PATHWAYS

APPC or NETBIOS

NETBIOS may be the communication interface of choice for LANs, but APPC promises cooperative processing for the entire IBM line.



MICHAEL HURWICZ

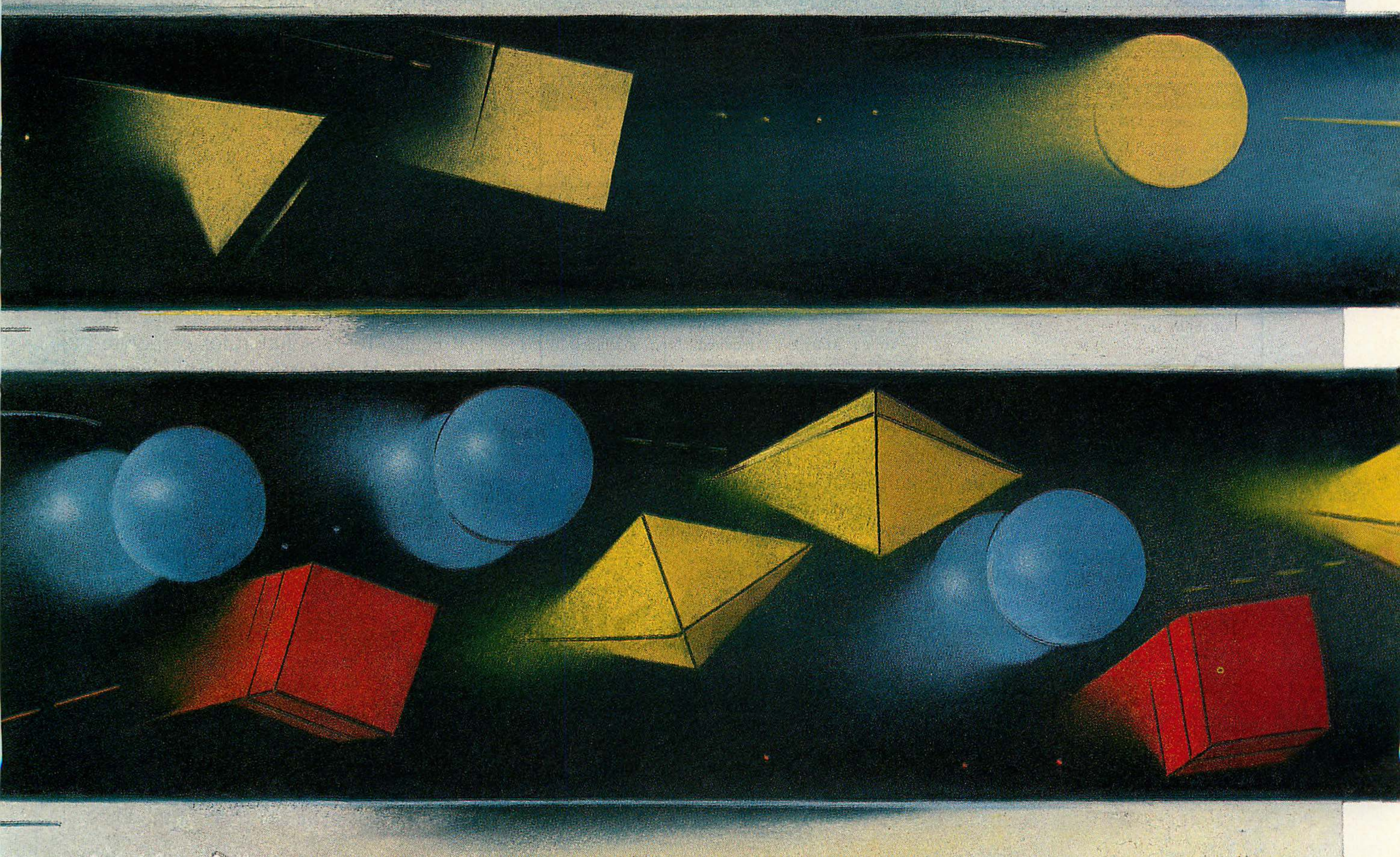
The big race is on between APPC (Advanced Program-to-Program Communication) and NETBIOS (Network BIOS), IBM's two major local area network (LAN) communication interfaces. APPC promises true program-to-program connectivity among dissimilar machines in a network, but so far has no commercial applications in the PC world. NETBIOS is widely implemented, but is limited to communications among microcomputers. While too early to declare one the interface of choice, each can be examined to understand its uniqueness and its potential.

APPC provides peer-to-peer communication among all cooperating programs in a network—programs running in the same building or halfway across the world on IBM's microcomputers, minicomputers, and mainframes, or other vendors' products. It is the most recent step in the evolution of IBM's Systems Network Architecture (SNA), from its terminal-oriented past. Further, it is a strategic part of IBM's broad System Application Architecture (SAA) introduced last March, an all-encompassing set of interfaces and protocols designed to provide a consistent, familiar environment for applications and users across a broad range of IBM products. The first SAA environment—and, perhaps, the first real test of APPC in the world of microcomputers—will be IBM's Operating System/2 (OS/2), to be released in stages starting in the first quarter of 1988.

NETBIOS is the foundation for IBM's existing PC LAN Program. NETBIOS is widely available, requires less memory than APPC implementations, and is relatively uncomplicated. Introduced in March of 1984 with the announcement of the PC Network, NETBIOS has become a de facto standard for PC-based LAN communications. Most major LAN operating system vendors provide a NETBIOS interface, including AST Research, Banyan, Excelan, Novell, 3Com, and IBM.

Although APPC was introduced for IBM's mainframe environment in 1982, the PC version, APPC/PC, was not released until 1986 and was limited to IBM's Token-Ring Network and Synchronous Data Link Control (SDLC). Last April, APPC/PC gained of support for PC Network hardware, with IBM's announcement of its Local Area Network Support Program.

ILLUSTRATION • CARY HENRIE



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NETBIOS AND APPC

Most current real-world uses of APPC center around IBM's office automation architecture, its Distributed Office Support System (DISOSS), which is used mostly on mainframes and minicomputers (see the accompanying sidebar, "APPC in the Real World," for a detailed description). A subset of APPC is contained in IBM's Enhanced Connectivity Facilities (ECF), a transparent microcomputer-to-mainframe link used for transferring files, sharing printers, and servicing virtual disks. APPC is also used in NetView and NetView/PC, IBM's network-management applications, and in its Distributed Data Management (DDM) architecture, which allows transparent record-level access to files on remote machines. Other mainframe and minicomputer vendors have implemented APPC, but, so far, only IBM offers APPC on a microcomputer as a commercial product for end users.

HOW THEY STACK UP

Although APPC and NETBIOS both provide network communication interfaces and can support microcomputers, they differ in a number of significant ways, including the environments for which they have been implemented, the functions and features they offer, and the completeness of their definitions. They are alike in that each requires an underlying communications system. In both cases, vendors are likely to use their own preferred protocols to implement those underlying systems.

However, the two interfaces were designed for different purposes. APPC is specifically designed to be an *any-to-any* protocol, providing a standard program-to-program communications interface, independent of operating systems, hardware, programming languages, data formats, communication protocols, and network configurations. It is also IBM's solution for corporate distributed processing, in which geographically separated programs can share and process information.

NETBIOS, however, is used almost exclusively in the microcomputer LAN environment. Few vendors plan to support it on minicomputers or mainframes. Its main strength is that it is well-established as a standard. Additionally, its lack of definition for all but the program interface means that it can be layered over most vendors' existing protocols. The long-term prognosis for NETBIOS is uncertain, however. Although IBM is emphasizing APPC as its future direction, it has included a NETBIOS interface in the OS/2 Communications Manager (part of the OS/2

APPC IN THE REAL WORLD

The major group of products and architectures using APPC today are those associated with IBM's DISOSS. The purpose of DISOSS is to allow various IBM systems to store, retrieve, and exchange documents, including text files and messages. The DISOSS products that use APPC are:

- SNA Distribution Services (SNADS), an architecture for the store-and-forward distribution of the following: text files, documents, image streams, and binary data.
- Document Interchange Architecture (DIA), which defines rules and data structures for exchanging distribution objects. Neither SNADS nor DIA is inseparable from DISOSS. If either migrates to another environment, APPC comes with it.
- Personal Services office-automation software, which supports word processing, electronic mail, document distribution, library services, and printing, and uses SNADS, DIA, and DISOSS to transfer information. (Document Content Architecture, or DCA, which defines the form and meaning of a document's contents, uses SNADS and DIA, but not APPC, because it is not a communications architecture.)

Other APPC implementations include:

- Distributed Data Management (DDM), an IBM distributed file-access architecture, is built on APPC. It allows the computer's operating system to transparently find a file or record on another machine and transfer it to the local machine. DDM/PC is the PC version of DDM.
- NetView and NetView/PC, IBM's host-based network management applications, use APPC as its communications system. They allow IBM and non-IBM products to send status information and alerts to a mainframe, so that the entire network can be managed from one central location. NetView/PC uses APPC protocols internally; it does not, however, require APPC/PC.
- Enhanced Connectivity Facilities (ECF) is a set of applications for interconnecting PCs and System/370 hosts running MVS/XA or VM operating systems. Announced in June 1986 for availability late in 1987, ECF can be used, for example, to access host resources such as printers, virtual files, or virtual disks. ECF includes two types of programs: *requesters*, which run in PCs and request service from hosts; and *servers*, which run in hosts and satisfy requests. These two types of programs communicate using the Server-Requester Programming Interface (SRPI). SRPI uses a subset of APPC that contains the ALLOCATE, DEALLOCATE, SEND_DATA, and WAIT_AND_RECEIVE verbs. However, programs using SRPI do not issue these verbs, but use a simpler programming interface based on requests and replies. SRPI is like a macro, performing the APPC functions with one issuance of a request or reply. Thus, SRPI shields servers and requesters from the underlying communications environment. Although simpler, it is less powerful and flexible. SRPI will be available, initially at least, only for PCs and System/370s, not for System/3x machines. Furthermore, the PCs must be the requesters, and the System/370s, the servers. Therefore, ECF and SRPI cannot be used for PC-to-PC communications.
- Advanced Peer-to-Peer Networking (APPN) was originally designed for the IBM System/36 minicomputer, although it may be developed for other machines in the future. APPN provides two main functions: decentralized routing and dynamic-network reconfiguration.
- Decentralized routing allows peripheral nodes to perform intermediate routing functions. Traditionally, routing in an SNA network was performed by *subarea nodes*, such as host computers (mainframes) or communication controllers (3725s, for example) attached to mainframes. *Peripheral nodes*, such as cluster controllers, minicomputers, and microcomputers, could not route messages. Therefore, sessions between peripheral nodes had to be established by a host node; with APPN, a session can be established by an APPN node.

Dynamic-network reconfiguration allows the System/36 to modify lists of known nodes on the fly. Traditionally, routing tables in SNA networks were modified through a SYSGEN operation, which required bringing down the network. Routing tables in APPN nodes can be modified as needed, without a SYSGEN.

The "control points" (CPs), or control functions, in one APPN node use APPC to communicate with control points in other APPN nodes. Functions managed by CPs include connectivity services (establishing new links or defining new nodes), directory services (identifying which nodes contain which LUs), route-selection services, session activation, and data transport. APPN enables APPC sessions to traverse multiple APPN nodes. The routing capability of APPN allows two nodes with no direct point-to-point connection to establish a session without going through a host.

APPN is based on low-entry networking (LEN). LEN, as it is currently available, refers to node type 2.1. (NT2.1 was previously called physical unit 2.1, or PU2.1.) NTs describe a network node's capabilities in managing various network resources (sessions, for example). In order to implement peer-to-peer connectivity, IBM created NT2.1, which is an enhanced version of NT2.0. NT2.1 allows two peripheral nodes to establish a session without going through a host and to operate multiple sessions simultaneously. It does not, however, offer any routing capability.

APPN is an NT2.1 enhanced to support routing capabilities, the ability to serve as an intermediary between two other nodes. NT2.1 nodes without routing capabilities are LEN nodes but not APPN nodes. (Some confusion has surrounded these terms since IBM developers published a paper in *The IEEE Journal on Selected Areas in Communications*, Vol. SAC-3, No. 3, May 1985, that described a system the authors called LEN. The LEN described in that paper is really the APPN of today. LEN version 1.0, as it was released in June 1986, is essentially the same as NT2.1.

Because PCs do not support NT2.1 at present, they are currently excluded from LEN. However, because PCs are typically connected by LANs, which are broadcast media, they have perhaps less need for routing functions or multiple-session abilities. The PC can support any number of sessions over the LAN, and the LAN delivers messages to any node on the LAN without the PC performing any routing functions. A minicomputer or mainframe, on the other hand, is typically connected to nonbroadcast media such as SDLC links. Here routing and multiple-session abilities are more essential.

—*Michael Hurwicz*

Version 1.1 Extended Edition). Microsoft is supporting a NETBIOS interface in its OS/2 LAN Manager.

The two interfaces are somewhat similar in terms of the basic functions they support. In the APPC, these functions are defined by a set of *verbs*. These APPC verbs, at the heart of the APPC application programming interface (API), compare roughly with NETBIOS commands (see tables 1 and 2). However, a direct comparison is somewhat deceptive—at first glance, it might even appear that NETBIOS is superior to APPC, because of its SEND BROADCAST, RECEIVE BROADCAST, and RECEIVE ANY commands.

In reality, APPC is endowed with a rich variety of options, while NETBIOS does only what a communications protocol must do—allow computers to transfer packets of information. APPC, for example, contains options to recover from errors in applications, confirm the receipt of information, and provide security; NETBIOS provides none of these options.

Because of their complex nature, some APPC implementations use large amounts of memory. APPC/PC implementation may need as much as 300KB of memory. Compared with these requirements, NETBIOS's memory needs are modest indeed. A complete implementation of NETBIOS using IBM's LAN Support Program on the Token-Ring requires only 30KB. Of course, a program that requires sophisticated communication in a NETBIOS environment will have to create its own facilities; an APPC environment, in contrast, already provides those facilities.

TABLE 1: ***APPC Verbs***

APPC VERB	DESCRIPTION
BASIC CONVERSATION VERBS	
ALLOCATE	Allocate a session between two LUs and establishes a conversation between two TPs.
CONFIRM	Request confirmation of a transmission.
CONFIRMED	Confirm reception and correct processing.
DEALLOCATE	Deallocate a conversation.
FLUSH	Flush send buffer of the local LU.
GET_ATTRIBUTES	Get attributes of a conversation.
POST_ON_RECEIPT	Specify TP routine to execute on receipt of transmission.
PREPARE_TO_RECEIVE	Change the conversation state from send to receive.
RECEIVE_AND_WAIT	Cause LU to wait for information to arrive, and deliver it to the TP when it does.
RECEIVE_IMMEDIATE	Receive information that is available immediately, but do not wait for information to arrive.
REQUEST_TO_SEND	Request permission of partner TP to enter send state.
SEND_DATA	Put information in the send buffer.
SEND_ERROR	Inform remote TP of an error.
TEST	Test a conversation to see if the local LU has received a REQUEST_TO_SEND.
TYPE-INDEPENDENT CONVERSATION VERBS	
GET_TYPE	Return conversation type (basic or mapped).
BACKOUT	Back out of a transaction; return to a previously established point of mutual consistency (synchronization point).
SYNCPT	Establish a new synchronization point.
WAIT	Wait for posting to occur.
CONTROL-OPERATOR VERBS	
INITIALIZE_SESSION_LIMIT CHANGE_SESSION_LIMIT RESET_SESSION_LIMIT	Initialize and change the maximum number of sessions which may exist between two LUs.

APPC AND OTHER PROTOCOLS

Unlike other IBM communication protocols, APPC is designed to allow cooperating programs to share both information and resources without sacrificing the power and capabilities of any machine on the network. With older forms of SNA network protocols, PCs used some form of terminal emulation, in which the PC acts like a terminal for a mainframe or minicomputer. This approach, however, has limitations.

First, terminal emulation is inflexible in accessing information. Standard microcomputer-to-mainframe software allows the transfer of either an entire screen or a complete file. It does not allow transfer of specific pieces of information in a file, although this is often exactly what is needed.

Second, when non-text information, such as financial data, is brought down to the PC environment, it often is not in a form that can be used easily by PC programs such as spreadsheets or database managers. Third-party software or custom-programming are usually required to transform the data into a usable format.

Third, when using terminal emulation software, users must learn how to operate the minicomputer or mainframe, increasing training time and the likelihood of errors. Most PC users would rather not know that the minicomputer or mainframe exists—they would rather use larger systems in the same way they use PCs.

In trying to solve these problems, developers have been hampered by a lack of programmers who can work in multiple environments (microcomputer, minicomputer, and mainframe) and a shortage of widely accepted protocols for facilitating communication among these different environments. Instead, they have adapted protocols from one environment to work in another. For example, IBM's Virtual Telecommunications Access Method (VTAM) protocols, which were designed to support terminal-to-host communications, have been pressed into service for PC-to-host and LAN-to-host communications. Limitations in the VTAM protocols have, in turn, led to limitations in the communications software based on it. APPC is intended to provide a basis for software to overcome such limitations.

HOW APPC WORKS

APPC was designed as an enhancement to SNA, IBM's overall networking plan. In SNA terminology, each product (processor, workstation, controller) on a network is called a *node*. Contained within each node is software that implements a *logical unit* (LU) and a *physical unit* (PU). An LU is a piece of code embodied in the software or firmware that enables the node to communicate with other nodes on the network; it also provides the user interface to the network. A PU program services the LU, managing certain network re-

APPC VERB	DESCRIPTION
CONTROL-OPERATOR VERBS *(continued)*	
PROCESS_SESSION_LIMIT	Negotiate a change in the session limit with a remote LU.
ACTIVATE_SESSION	Activate a session.
DEACTIVATE_SESSION	Deactivate a session.
DEFINE_LOCAL_LU	Define the name for the local LU, and initialize or change parameters that control the operation of the local LU.
DEFINE_REMOTE_LU	Change parameters that control the operation of the local LU in conjunction with a remote LU.
DEFINE_MODE	Change parameters that control the operation of the local LU in conjunction with a group of sessions to the specified remote LU (the session group is identified by a mode name).
DEFINE_TP	Initialize or change the parameters that control the operation of the local LU in conjunction with a transaction program.
DISPLAY_LOCAL_LU	Return current values of parameters that control the operation of the local LU.
DISPLAY_REMOTE_LU	Return current values of parameters that control the operation of the local LU in conjunction with a remote LU.
DISPLAY_MODE	Return current values of parameters that control the operation of the local LU in conjunction with a group of sessions.
DISPLAY_TP	Return current values of parameters that control the operation of the local LU in conjunction with a transaction program.
DELETE	Delete parameter values established by the DEFINE verbs.

Conversation verbs are used to send data between transaction programs (TPs); control verbs change parameters related to the session or logical unit (LU). Applications typically used mapped conversation verbs, which use the same name as the basic verbs, but have "MC_" prepended to them.

sources and functions, such as establishing sessions. For example, a PU type, also called a *node type* (NT), determines whether the node can support multiple sessions or perform intermediate routing functions.

APPC is a particular type of LU known as LU6.2. It allows any application program on a network to perform a unit of work, or *transaction*, in cooperation with one or more other application programs on the network. Every participating program is called a *transaction program* (TP). An *application* TP is written by end users or software developers for end users. A *service* TP offers a service to an application TP.

TPs communicate indirectly through their respective LUs (see figure 1). The connection between the two LUs is called a *session*; the actual exchange of information between the two TPs is called a *conversation*. Only one conversation can use a session at a time, but any number of conversations can take turns using the same session; when this happens, the conversations are said to *time slice* the session.

To initiate APPC, transaction programs issue verbs accompanied by proper parameters (see table 1 for a listing of the verbs). The APPC software then executes the verbs, providing the desired services to programs.

The APPC verbs are divided into subsets according to their functions. Each subset must be implemented in its entirety, or not at all. This offers some flexibility to implementors, while greatly reducing the number of different versions of APPC. The APPC verbs are referred to collectively as the *protocol boundary*. The LU executes the verbs in order, as they are issued.

Figure 2 shows the *format box* for the CONFIRM verb, which asks for confirmation that a remote program has received and successfully processed a previous transmission. When issuing CONFIRM, the only parameter the program must provide is the *resource* that identifies the conversation.

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TABLE 2: *NETBIOS Commands*

COMMAND	DESCRIPTION
RESET	Set available sessions and commands to default values.
STATUS	Get status of LAN adapter card.
ADD NAME	Register a NETBIOS name at the local station.
ADD GROUP NAME	Register a NETBIOS group name at the local station.
DELETE NAME	Deregister a NETBIOS name at the local station.
CALL	Attempt to open a session with a remote NETBIOS node; like APPC ALLOCATE.
LISTEN	Make the local node available to accept a CALL.
HANG UP	Close a session with a remote node; like APPC DEALLOCATE.
SEND	Send data over session; like APPC SEND_DATA.
CHAIN SEND	Send multiple buffers of data; like APPC SEND_DATA.
RECEIVE	Receive data from a specific session; like APPC RECEIVE_AND_WAIT and RECEIVE_IMMEDIATE.
RECEIVE ANY	Receive data from anyone with whom you have a session.
SESSION STATUS	Obtain status of NETBIOS session, information such as receive, listen, and call commands outstanding, and whether the session is established or pending, is completed or aborted.
SEND DATAGRAM	Send one packet without creating session.
SEND BROADCAST DATAGRAM	Send datagram to all listening nodes.
RECEIVE DATAGRAM	Receive one datagram; like APPC RECEIVE_AND_WAIT and RECEIVE_IMMEDIATE.
RECEIVE BROADCAST DATAGRAM	Receive a broadcast datagram from another node.

NETBIOS supports three basic communication methods: sessions, datagrams, and broadcast datagrams. Sessions require setup with the LISTEN and CALL commands, and provide point-to-point acknowledged data transfer. Datagrams do not require setup; they send unacknowledged messages. Broadcast datagrams send a message to all listening nodes. NETBIOS itself uses this feature to guarantee unique names.

Verbs are either *control verbs*, which manipulate some aspect of the LU environment, or *conversation verbs*, which are used to communicate between nodes. The conversation verbs are either *basic*, for use by service TPs, or *mapped*, for use by application TPs. Although the two kinds of conversation verbs perform essentially the same tasks, the basic conversation verbs support more parameters and options than the mapped conversation verbs do, and, therefore, are more flexible, more powerful, and more difficult to use.

For each verb, the architecture defines both the syntax (how the verb is used) and the semantics (what it means). For example, ALLOCATE means, "I want to start a conversation with you." SEND_DATA means, "I want to send these data to you." DEALLOCATE means, "I want to end this conversation with you."

Each verb does not necessarily cause a transmission. Control verbs never cause a flow between the programs. Even with conversation verbs, the LU can delay or omit transmission. It might delay transmission to economize the communications bandwidth by combining several transmissions, sending, for example, an allocation request, the data, and a deallocation request all together in one line flow. It omits transmission when the conversation verb executes in local mode. For example, suppose program *X* sends a deallocation request (asking permission to "hang up"), which program *Y* confirms (answering "all right"). When the conversation has completed, program *Y* can issue a local DEALLOCATE to discard the control information for the conversation; because the verb is used locally, nothing goes out over the line.

Figure 3 shows a simple APPC conversation, initiated by TP *A*. (To compare it with a typical NETBIOS conversation, see figure 4.) In the APPC conversation, TP *A* issues an ALLOCATE, a SEND_DATA, and a DEALLOCATE. When the transmission reaches the LU at the remote node, the LU starts up TP *B* (if it is not already running) and TP *B* issues a RECEIVE_AND_WAIT verb. (Some implementations, like the one in figure 3, use two RECEIVE_AND_WAIT verbs.) TP *B* then confirms it has received the data and the deallocation request. The LU that is at TP *A*'s node returns an OK return code to TP *A*'s DEALLOCATE and ends the conversation. Afterward, TP *B* issues a local DEALLOCATE and discards its control information for the conversation.

A NETBIOS conversation, shown in figure 4, follows the same general course as the APPC conversation, with some important differences. First, program B must already have issued the NETBIOS LISTEN command and be waiting for a CALL. This is in contrast to APPC, where the transaction program will be started if not already running. Second, the CALL and SEND commands are always separately acknowledged. APPC has more flexibility about when data and acknowledgements are sent, allowing data from multiple verbs to be transmitted in one operation. It is possible, however, for an APPC TP to ensure that messages are sent immediately by using the FLUSH verb.

Although NETBIOS can be defined rather clearly by a simple list of the commands it provides, APPC is a much more complex product. Each verb has a myriad of choices, not all of which are available in every implementation of APPC. In addition, the association of APPC with SNA means that APPC programmers should be familiar with IBM's communication architecture.

TOWERS OF OPTIONS

APPC verbs are divided into several different function sets; two are *base* and the rest are *optional*. One base set contains basic conversation verbs, and the other, mapped conversation verbs. All complete implementations of APPC support the base set containing the basic conversation verbs. Any APPC implementation offering an open API (allowing user-written programs) must support both base function sets. Imple-

mentations lacking a programming interface for APPC can offer just the basic conversation verbs.

The optional function sets, as their name implies, can be included or omitted in any given implementation. However, each optional set must be treated as a whole—if one verb in the set is offered, they must all be offered. The optional function sets are typically depicted as *towers* built on the base function sets (see figure 5).

APPC offers five types of optional function sets. The first set contains a mapping function that allows TPs to designate transformations, or *maps*, to be performed on data at sending and receiving nodes; a map might, for example, transform the data received in a data stream into a binary format compatible with the receiving machine. The user defines the record format and transformation to be performed.

The second option is the *sync point* function set, which allows programs to establish mutually agreed-upon synchronization points in their processing. These are points at which all programs and data are verified as consistent. Cooperating programs can return to a sync point in case one program has an error. By returning to a sync point and starting over, the programs can continue processing successfully despite the error.

The third option allows an application TP to define and supply program-initialization parameters (PIPs) with an allocation request to another TP. This information is meaningful only to the application TPs. The fourth option type offers several security-option sets, including user IDs and passwords, and the last, a number of option sets to improve performance.

SNA LAYERS

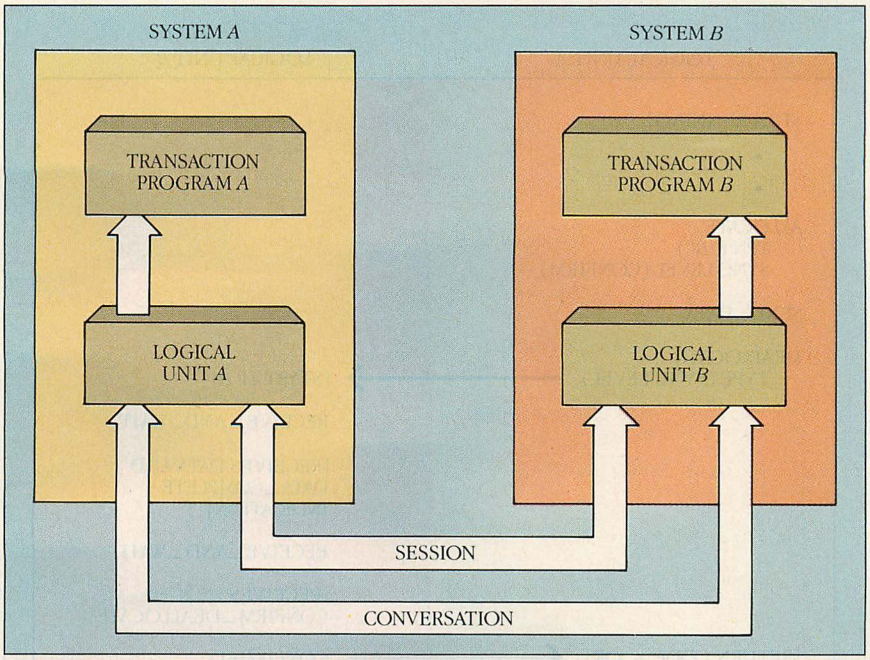
Figure 6 shows how the SNA layers are organized and where the APPC fits in. The layers of the Open Systems Interconnection (OSI) proposed by the International Organization for Standardization (ISO) are included for comparison. Both architectures have seven layers that are roughly equivalent. APPC defines the SNA layers between the path control and end-user layers; these include the Network Addressable Unit (NAU) services, data-flow control, and transmission control.

A more practical division of the APPC universe would be according to where the particular program or architecture resides: above the SNA layers; in the end-user layer; in the layers defined by APPC; in the path-control layer; or below the path-control layer (in the data-link or physical layers).

The TPs above the end-user layer are not defined by SNA. These are the application TPs written by end users or software developers. Although they are outside SNA, they still use SNA services. The service TPs are defined by SNA and reside at the end-user layer. The application TPs can issue APPC verbs or use commands provided by the service TPs. For example, IBM's Document Interchange Architecture (DIA) is a service TP that allows application TPs to transfer documents from one node to another. The DIA service TP issues the APPC verbs, and the application TPs issue the DIA commands (see figure 7).

The lower limit of the APPC specification is the point where APPC passes a basic-information unit (BIU) to the path-control layer. The path-control layer and the layers below (the data-link and physical layers) are not part of

FIGURE 1: ***Communicating over an APPC Session***



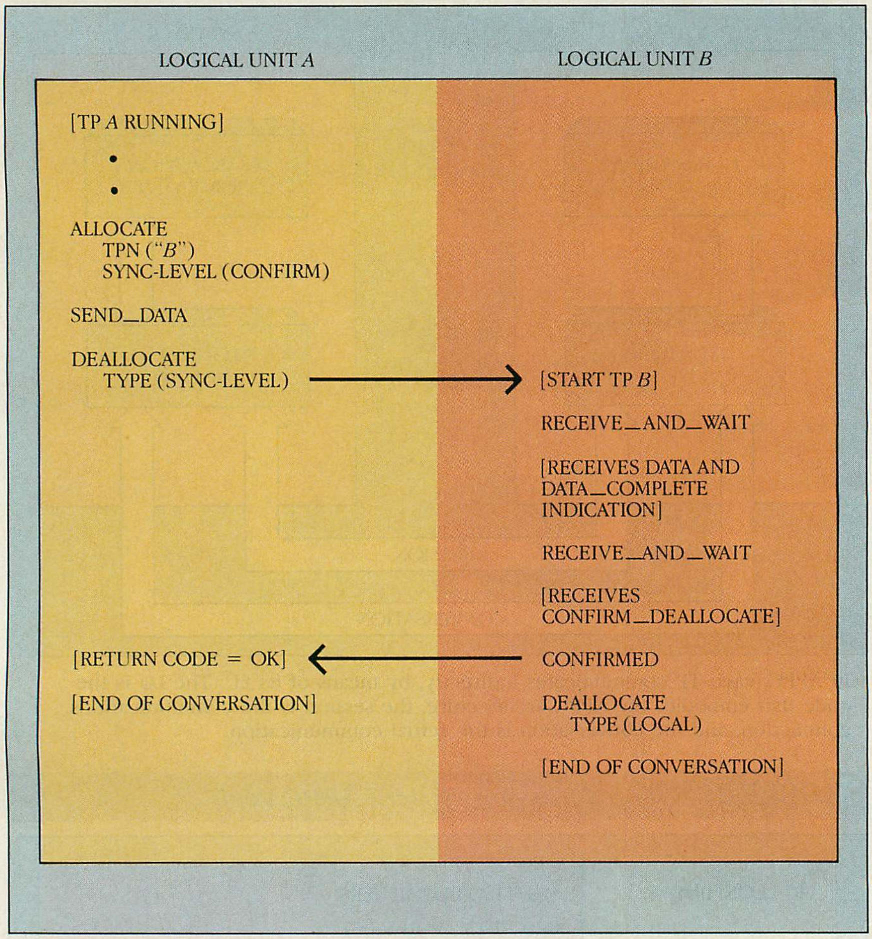
In APPC, each TP communicates indirectly, by means of its LU. The LU is the code that embodies the APPC architecture, the session is the communications connection, and the conversation is the actual communication.

FIGURE 2: ***Format Box for Typical APPC Verb***

MC_CONFIRM	SUPPLIED PARAMETERS RESOURCE (VARIABLE)
	RETURNED PARAMETERS RETURN_CODE (VARIABLE) REQUEST_TO_SEND_RECEIVED (VARIABLE)
	;

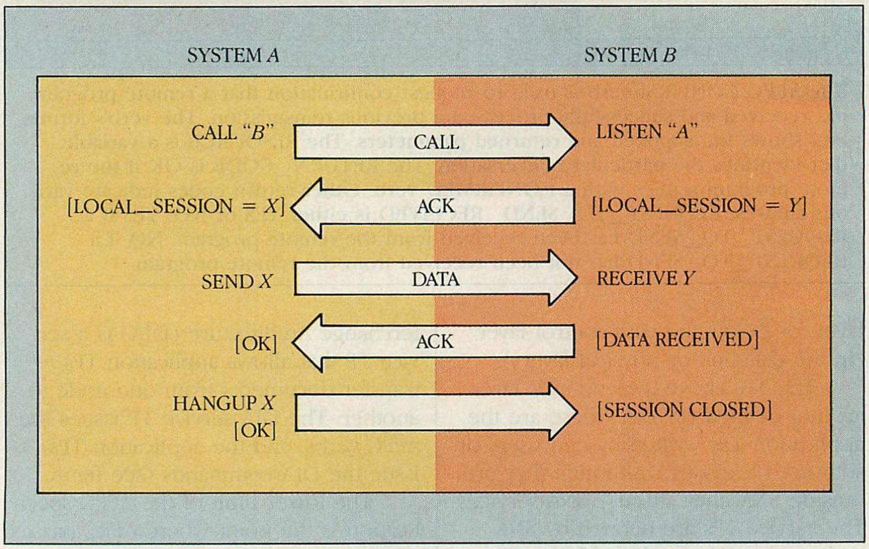
The APPC CONFIRM verb is used to request confirmation that a remote program has received and successfully processed a previous transmission. The verb's format box shows the supplied and returned parameters. The RESOURCE is a variable that identifies the particular conversation. The RETURN_CODE is OK if the remote program replies with a CONFIRMED verb. Other return codes indicate various failures. REQUEST_TO_SEND_RECEIVED is either YES or NO: YES if a REQUEST_TO_SEND has been received from the remote program, NO if a REQUEST_TO_SEND has not been received from the remote program.

FIGURE 3: *APPC Conversation*



The APPC conversation is initiated by TP *A*, which issues an ALLOCATE, SEND_DATA, and a DEALLOCATE. When the transmission reaches the LU at the remote node, the LU starts up TP *B*, which issues a RECEIVE_AND_WAIT verb and confirms receipt. LU *A* issues a confirmation and ends the conversation.

FIGURE 4: *NETBIOS Conversation*



A NETBIOS session is initiated by CALL and LISTEN. The caller must specify a CALLNAME when issuing the CALL. The receiver specifies a CALLNAME when issuing the LISTEN or opts to listen for any call that arrives. All SENDs in a session are acknowledged end-to-end and a status is returned to the sender.

the LU. Because the APPC architecture does not specify how the BIUs must be passed from one node to another, APPC is compatible with whatever protocol is being used.

Sometimes, however, an APPC implementation must provide functionality below the specified lower limit in order to interface with a given piece of hardware. In particular, some APPC implementations must provide path-control functions. The IBM LAN Support Program, for example, which supplies the highest-level interface to IBM's LAN adapter cards (Token-Ring Network and PC Network), has a data-link control (DLC) interface. The same is true of synchronous data-link control (SDLC) adapter cards, which frequently are used for microcomputer-to-mainframe links. Because these interfaces do not provide a path-control layer interface, APPC/PC, which is designed to run on both SDLC and LAN hardware, must provide path-control functions to bridge the gap between what the APPC architecture defines and what the adapter cards provide.

The data-link and physical layers are typically embodied in hardware, usually an adapter card. The software to handle the adapter also resides in the data-link layer. For example, when originally released, IBM's Token-Ring Network adapter came with an adapter-handler program called TOKREUI.COM (for Token-Ring Extended User Interface), which had an IEEE 802.2 standard interface—a DLC interface. In April 1987, IBM chose to replace TOKREUI.COM with the LAN Support Program, which also works on the IBM PC Network adapters, thus extending APPC/PC support to the PC Network.

The 802.2 standard interface defines both a logical-link control (LLC) and a medium-access control (MAC) sublayer. The LLC interface offers two kinds of service: connectionless (type 1) and connection-oriented (type 2). The connectionless service handles each message unit independently of any others and does not number units as they are transmitted. The connection-oriented service numbers the units, which helps ensure that message units arrive in order, and that none is missing or duplicated. APPC/PC uses the connection-oriented, type 2, service.

A MAJOR DIFFERENCE

Figure 6 points out an important difference between APPC and NETBIOS for vendors trying to attain compatibility with these standards. APPC is much more completely defined than NET-

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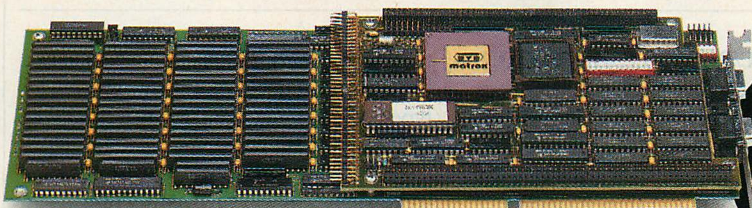

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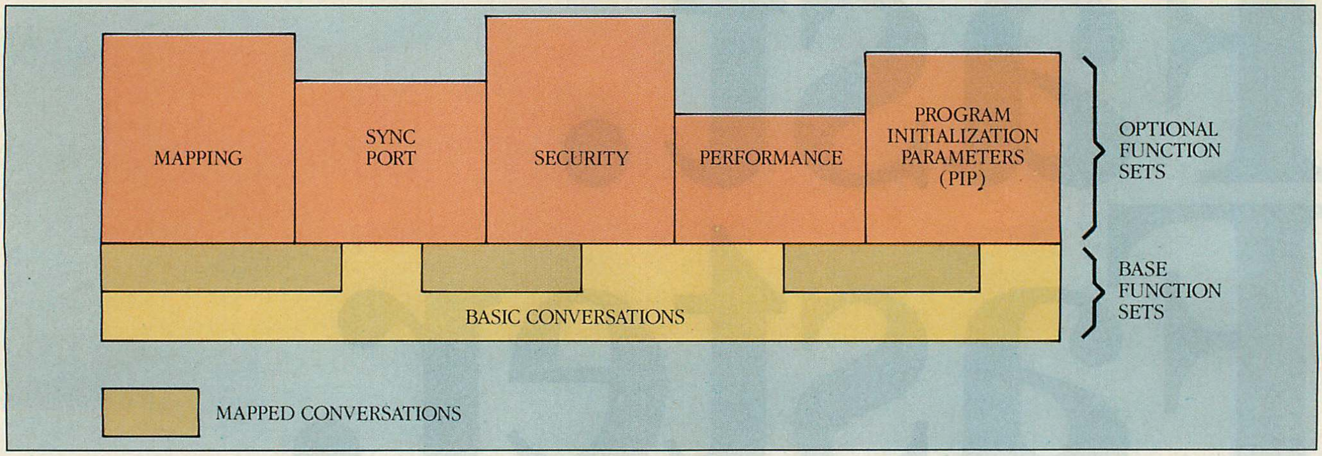
FIGURE 5: ***APPC Optional Function Sets***



APPC's optional function sets are depicted as towers built on the base function sets. They include options to map formats, establish synchronization points, define program-initialization parameters (PIPs), provide security, and enhance performance.

BIOS—in essence, NETBIOS is merely a programming interface.

Conceptually, NETBIOS occupies only the very top of the OSI session layer (layer 5). To build a complete communications system, the developer must go outside the NETBIOS definition. This is not important for applications, which use only the NETBIOS command interface—the very "top" of a NETBIOS implementation. However, the lack of definitions for lower layers makes it difficult to create a NETBIOS implementation that will interoperate with another vendor's NETBIOS, because interoperation requires compatibility at lower layers, too.

For example, in order to create a NETBIOS implementation that can talk to stations on IBM's Token-Ring Network running IBM's NETBIOS, a developer must emulate or duplicate not only the NETBIOS interface, Token-Ring hardware, and IEEE 802.2 interface (all of which are standardized), but also protocols contained in IBM's Token-Ring NETBIOS that have never been published, are not well known, and could be changed at any time. Such reverse engineering is risky.

APPC, on the other hand, is defined from OSI layers 4 through 6 (or their SNA equivalents). In addition, layers that are not defined by APPC can be taken safely from well-known SNA definitions. For example, to connect to an IBM host running APPC, a developer can emulate SDLC at the data-link layer, the SNA path-control layer above that, and then use APPC up to level 6. This constitutes a complete communication system, consisting of well-known protocols that are unlikely to change in the foreseeable future.

IBM'S APPC/PC IMPLEMENTATION

In APPC/PC, certain APPC functions are left to each particular installation or product to formalize. This so-called "application subsystem" software is not provided by IBM, and thus termed "user-provided" although, of course, it takes a programmer to produce it. These functions include answering incoming ALLOCATE requests and either rejecting them or transmitting them to the appropriate TP. The subsystem also defines characteristics of the PU and LU, activates hardware adapters, handles logged error messages, provides LU-to-LU passwords if required, and loads or cancels TPs when necessary. The programmer also can provide any other services that are desired in the application subsystem.

The interface between the application subsystem and APPC/PC consists of a verb interface and a set of exit routines. The application subsystem must respond to certain APPC/PC verbs by establishing the PU and LU, defining partner LUs, session limits, and other parameters. The exit routines manage incoming ALLOCATE requests, log errors, and provide passwords.

APPC/PC is a terminate-and-stay resident (TSR) program that is loaded by typing APPC at the DOS prompt. First, the 802.2 interface must be loaded; then the APPC/PC; next, the application subsystem; and, finally, any TPs that are to be active immediately. APPC/PC also can be unloaded using the APPCUNLD program supplied on the APPC/PC diskette.

When programming in assembly language, the developer can invoke APPC/PC verbs through DOS interrupt 68H. DS:DX points to the APPC/PC control block; the contents of this control block vary depending on the request type. Register AH contains the number of the APPC/PC request.

APPC/PC's memory requirements were presented in an IBM technical seminar as 158KB for the base code; 4.5 or 5.5KB for each additional LU; and 2.5KB for each additional concurrent conversation or session. However, APPC/PC has been known to require 214KB (not including DOS) for low-level communications protocols (such as the IBM LAN Support Program), the application-subsystem code, and any transaction programs. The IBM LAN Support Program, which can provide the 802.2 interface on the Token-Ring Network, requires about 8KB. With DOS and other necessary code, 300KB would not seem an unreasonable estimate, even if the application subsystem and the TPs are excluded.

NON-IBM IMPLEMENTATIONS

APPC is not limited to Token-Ring, SDLC, or 802.2 protocols. Because protocols below the path-control layer do not affect APPC compatibility, vendors with other successful protocols have continued to use them, if possible, when implementing APPC. DEC offers a DECnet/SNA Gateway that supports an APPC/LU6.2 programming interface, terminal connectivity, and various kinds of information transfer, including document exchange between DISOSS and the DEC office automation environment. To the VAX, the DECnet/SNA Gateway looks like an Ethernet connection. Only the link between the gateway and the IBM system is based on SDLC. The gateway translates between Ethernet and SDLC protocols.

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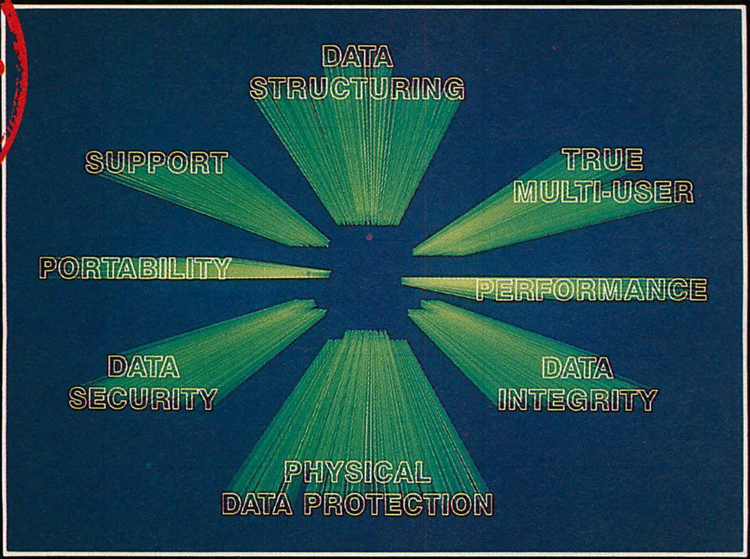

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FIGURE 6: *SNA and OSI Layers*

	SNA FUNCTIONS	SNA	OSI
	END-USER PROGRAMS	END-USER	APPLICATION
APPC	PRESENTATION SERVICES: FORMAT DATA FOR SPECIFIC APPLICATIONS OR TERMINALS; SESSION SERVICES: MANAGE NETWORK	NAU SERVICES	PRESENTATION
APPC	MAINTAIN SEND-RECEIVE MODES HIGH-LEVEL ERROR CORRECTION	DATA FLOW CONTROL	SESSION
APPC	SESSION-LEVEL PACING ENCRYPTION AND DECRYPTION	TRANSMISSION CONTROL	TRANSPORT
PATH NETWORK CONTROL	ROUTING SEGMENTING DATA UNITS VIRTUAL ROUTE PACING	PATH CONTROL	NETWORK
PATH NETWORK CONTROL	LINK-LEVEL ADDRESSING SEQUENCING ERROR CONTROL	DATA LINK	DATA LINK
	PHYSICAL PROPERTIES OF SIGNAL PIN ASSIGNMENTS ON CONNECTORS	PHYSICAL	PHYSICAL

Adapted from Inside APPC *by Michael Hurwicz (Architecture Technology, Minneapolis, MN, 1987)*

IBM's Systems Network Architecture (SNA) and the Open Systems Interconnect (OSI) model have seven, roughly equivalent layers. APPC, defines the Network Addressable Unit (NAU) services, data-flow control, and transmission control.

Vendors implementing a similar strategy include Data General in its Document Exchange Architecture (DXA), Unisys in its OFISbridge and Distributed Systems Services (DSS), Hewlett-Packard in its Office Connect to DISOSS, and Wang in its DISOSS Gateway. Although these products differ in detail, they are alike in that they minimize the use of SDLC protocols, using them only in the link from the gateway to the IBM system.

When connecting an IBM system to a non-IBM system using APPC, the link between the gateway and the IBM system must be compatible starting at the physical layer and continuing on through the NAU services layer. Without compatible physical and data links, it is not possible even to transfer bits from one machine to another. If the IBM system supports only Token-Ring and SDLC connections at the DLC layer, the gateway-to-IBM link must use one of them. The fact that both systems are using APPC implies compatibility through the NAU services layer.

However, once that link has been made, non-IBM vendors can continue to use their preferred protocols within their own networks. In addition to minimizing changes in the existing network, this approach isolates APPC as much as possible. Therefore, problems with the APPC link are less likely to affect the existing network.

In the microcomputer arena, LAN operating system vendors are likely to take the lead in implementing APPC. Vendors who have already announced support include Novell, Banyan, and 3Com. These vendors are almost certain to implement APPC in gateways, just as mainframe and minicomputer vendors have already done.

In a parallel experience from the recent past, most vendors put the NETBIOS protocols on top of whatever lower-level LAN protocols they favored. IBM first implemented NETBIOS on the PC Network adapter. Banyan, 3Com, and Novell emulated the NETBIOS interface, but not the PC Network adapter protocols, which, in fact, are proprietary and have never been published. Later, when IBM implemented NETBIOS for the Token-Ring Network adapter, IBM also abandoned the PC Network adapter protocols, creating a new implementation of NETBIOS for the Token-Ring Network.

PROS AND CONS

APPC is IBM's central protocol for use in program-to-program communications among dissimilar systems. Any intelligent machine capable of communication is a candidate for APPC. IBM has, in fact, implemented APPC on microcomputers, minicomputers, mainframes, image terminals, and printers. In addition, LAN vendors have pledged APPC support for non-IBM microcomputer LAN environments.

This could prove particularly important when implementing gateways to minicomputers and mainframes. Application programmers should welcome using the same high-level communication protocols on both sides of the gateway, rather than having to

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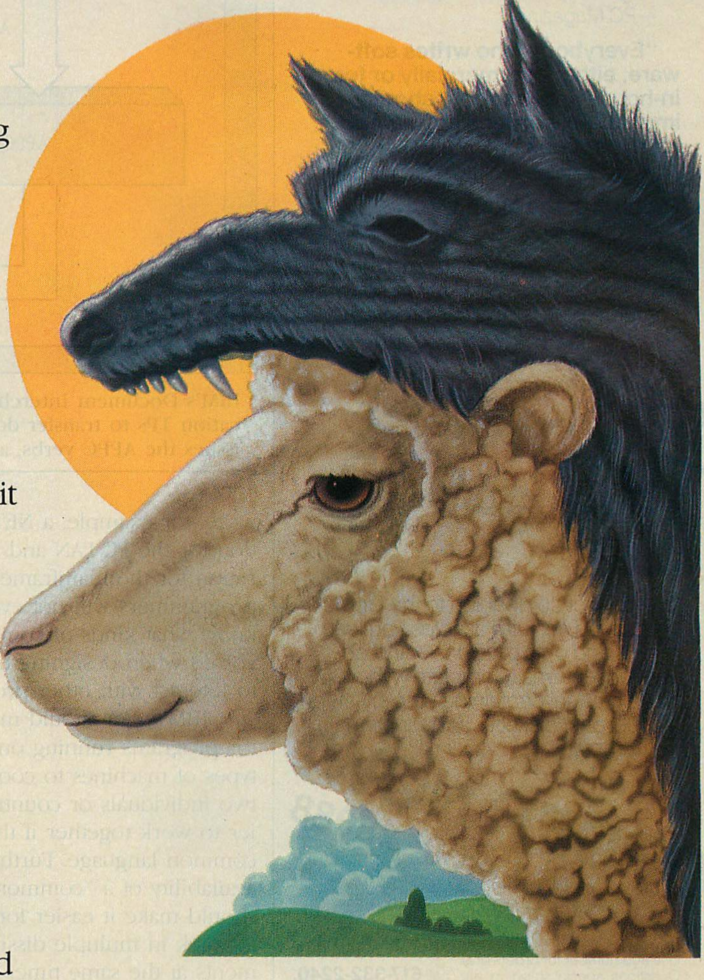

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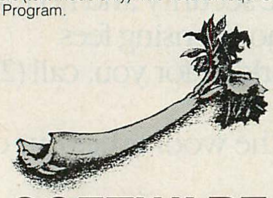

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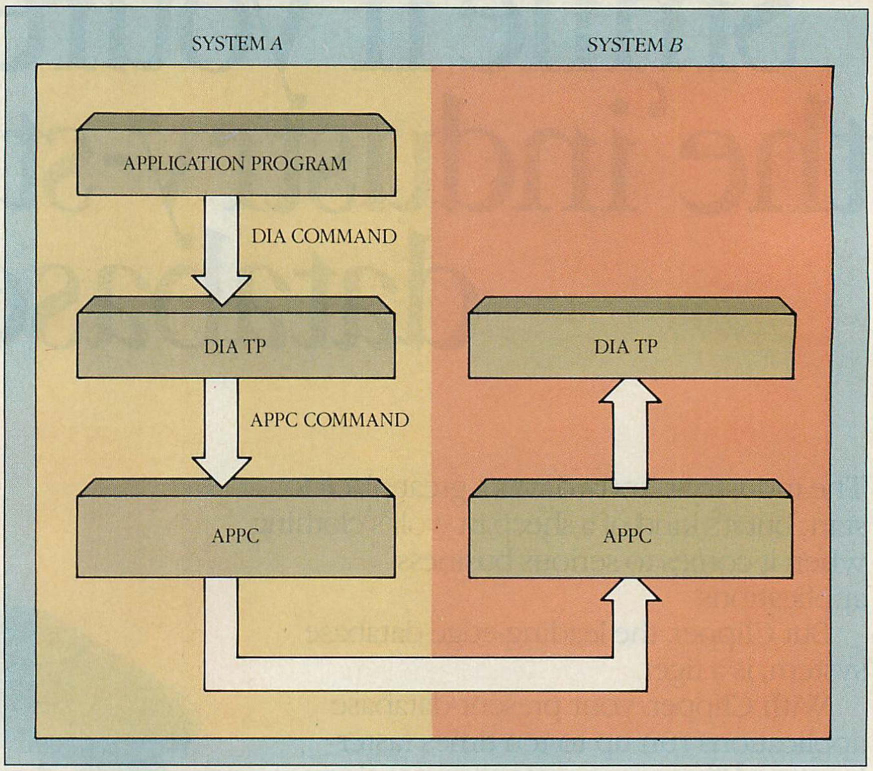
FIGURE 7: ***DIA Service TP***



IBM's Document Interchange Architecture (DIA) is a service TP that allows application TPs to transfer documents from one node to another. The DIA service TP issues the APPC verbs, and the application TPs issue the DIA commands.

write, for example, a NETBIOS application for the PC LAN and a VTAM application for the mainframe. With APPC, programmers will not even need to know what kinds of computers are involved when designing their programs to interact with other programs.

IBM's SAA should make it easier for programs running on different types of machines to cooperate, just as two individuals or countries find it easier to work together if they share a common language. Furthermore, the availability of a "common language" should make it easier for programmers to work in multiple dissimilar environments at the same time.

As the centerpiece of SAA's Common Communications Support, APPC will be an important standard for developers and users attempting to integrate dissimilar systems. Using the APPC interface as a communications gateway, vendors also will be able to tap into SAA environments.

To date, however, SAA is not in use and APPC's implementation on the PC is, quite frankly, a memory hog and has few practical applications. In addition, IBM's PC implementation is a bit of a memory hog. In fact, programmers may find that APPC/PC and its associated software take up so much memory that too little memory remains within the 640KB universe for their applications. Therefore, programmers may choose to wait for the appearance of OS/2 before they begin writing serious APPC applications on the PC.

APPC provides a basis for developers to address the limitations in the current crop of microcomputer-to-mainframe and microcomputer-to-minicomputer communications programs. The next logical step is for programmers to write the applications that will give users transparent information transfer and resource sharing across all systems.

NETBIOS, on the other hand, is a well-established standard in the PC world and is, therefore, widely supported. It provides basic transportation for packets of data and requires only a small amount of memory. For applications that remain within the PC LAN environment, programmers may be well advised to use the NETBIOS interface, at least for now.

Michael Hurwicz is a freelance writer and consultant based in Nashville. He is the author of Inside APPC, *published by Architecture Technology, Minneapolis, Minnesota.*

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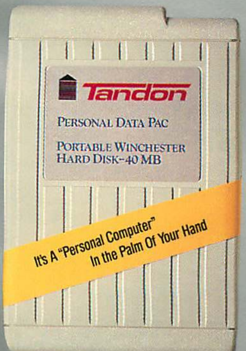

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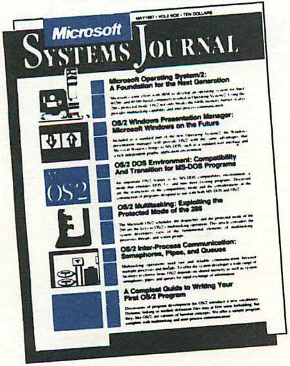

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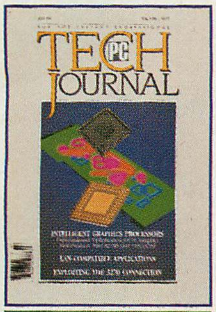

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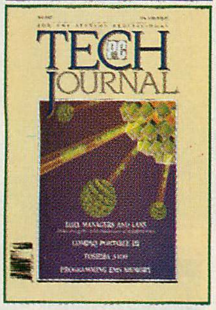

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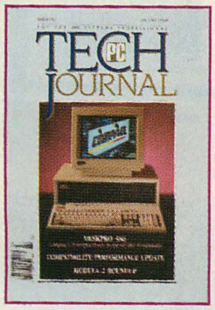

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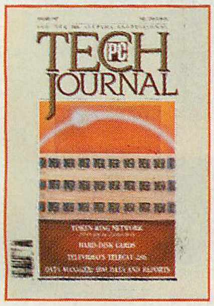

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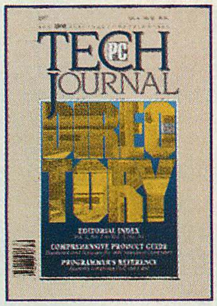

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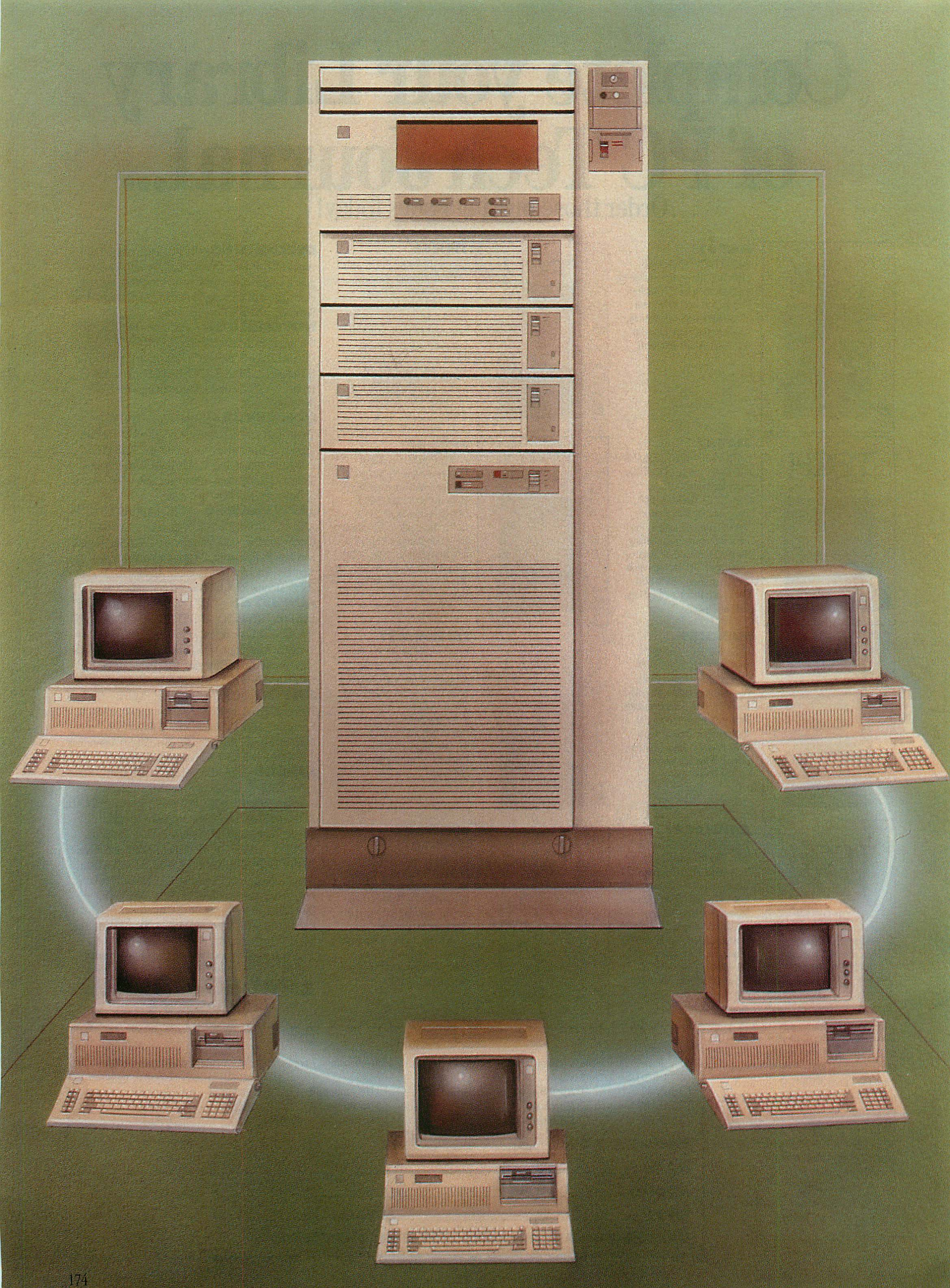

The 9370 Attraction

It may not be a VAX-killer, but IBM's 9370 offers clear advantages to the middle layer of the corporate computing hierarchy.

DENNIS LINNELL

Unlike many IBM products, the new 9370 information system entered the market with a sharp focus: it is a departmental processor for work groups within a large organization. It fills the gap between desktop PCs and the big 3090 processors in the corporate data center. It shares the same basic System/370 (S/370) architecture with the 3090, and its hardware facilitates the attachment of PCs using a variety of interconnection strategies and protocols. The 9370 has the look, feel, specifications, and price of a very serious computing device.

The obvious attractiveness of these features has prompted many large companies to order the 9370. Market research firms forecast that IBM will deliver an average of 20,000 systems per annum for the next few years, with some large customers installing at least 300. Given the 3090 as the standard centralized mainframe and the PC as the standard workstation, the 9370 is destined to become the middle layer of the corporate computing hierarchy. It is simply a matter of time until major users begin demanding excellent integration between the 9370 and the PC.

Indeed, connectivity is at the forefront of the computer market today, and the 9370 offers at least ten ways to connect to PCs and six ways to connect to larger S/370s. New IBM products often fail to deliver in this crucial area, but because the 9370 implements the S/370 architecture, practically all connectivity options for S/370 machines are instantly available. Many can be implemented in a practical and economical manner, using standard product features. Others are not so good. But it is certain that IBM and other companies will announce significant enhancements in the next few years.

As part of the usual speculation that precedes any important IBM product announcement, analysts called the 9370 a "VAX killer," a reference to the highly successful Digital Equipment Corporation (DEC) VAX minicomputer line. Although competitive in speed and price, the 9370 is not directly comparable with the VAX in terms of features. The 9370 features list is finely tuned to appeal to traditional "true blue" IBM customers, but it is doubtful that VAX aficionados will get excited. Indeed, DEC seems unconcerned. The 9370 is partially a defensive weapon to keep the VAX out of a few large IBM accounts, but, more importantly, it provides a more consistent architecture for complex IBM networks.

The 9370 is not a single computer, but a group of four machines based on S/370 architecture. All models feature modular, rack-mounted components,

ILLUSTRATION • ANDY LEVINE

PHOTO 1: *IBM 9370 Model 20*

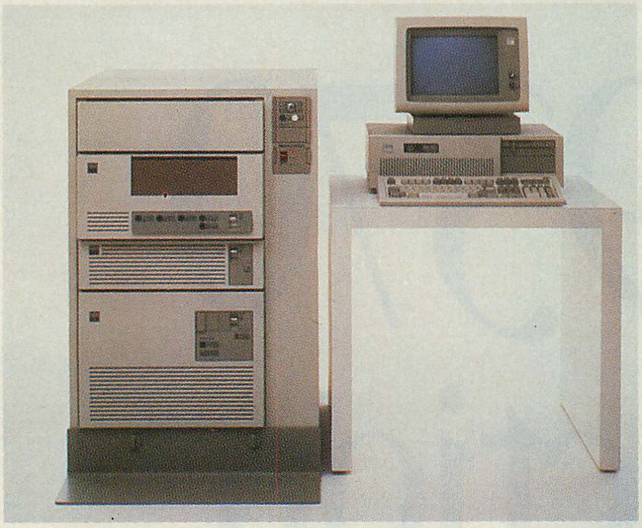

PHOTO 2: *IBM 9370 Model 90*

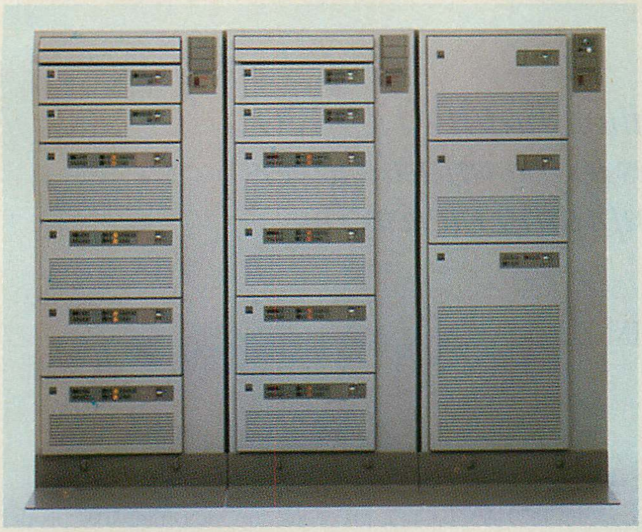

Photo 1: The Model 20 is the size of a small file cabinet, occupying only 7.8 square feet of floor space. It needs no special air conditioning and can be plugged into a standard wall outlet. The machine's processor, an IBM 9347 magnetic tape unit, and two 368MB disk drives can all be mounted in the Model 20's one-meter rack cabinet.

Photo 2: The Model 90 processor is the same height as the processor used in the Models 40 and 60. Rack space also is required for an I/O card unit. Thus, most Model 90 systems will be composed of two or more 1.6-meter cabinets.

Photo 3: The Model 40 and 60 processors are twice the height of the Model 20 processor. One processor, an 824MB disk subsystem, and an IBM 9347 magnetic tape unit can be mounted in a single 1.6-meter rack cabinet.

Photo 4: The processor logic functions of the 9370 Models 20, 40, and 60 are implemented with processor logic cards that use a new generation of IBM bipolar logic chips. These chips contain more than 4,000 circuits.

Photo 5: The 9370 includes dense memory packaging. As many as 80 one-megabit dynamic RAMs are packaged on each of the system's 8MB processor storage cards. Each memory card measures 9 inches high by 7 inches wide.

PHOTO 3: *IBM 9370 Model 60*

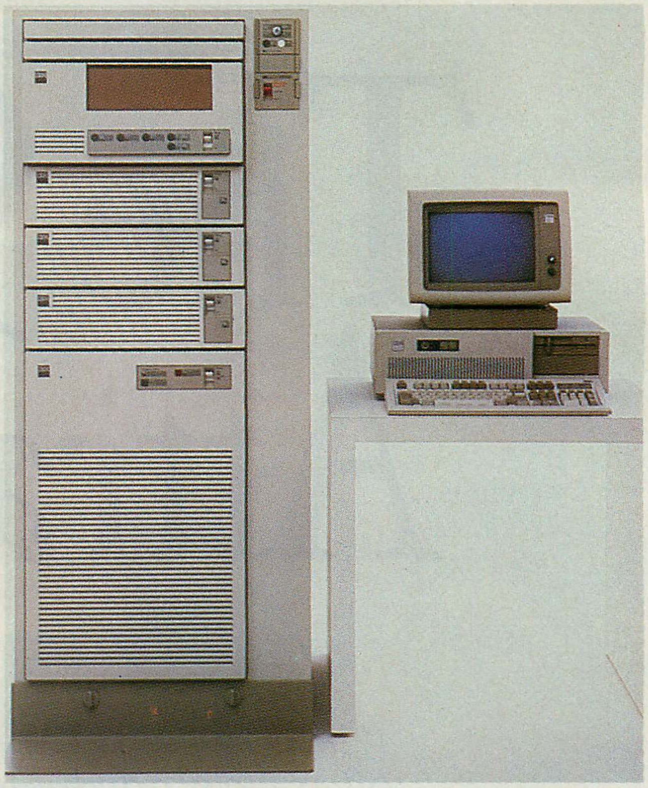

PHOTO 4: *Processor Logic Cards*

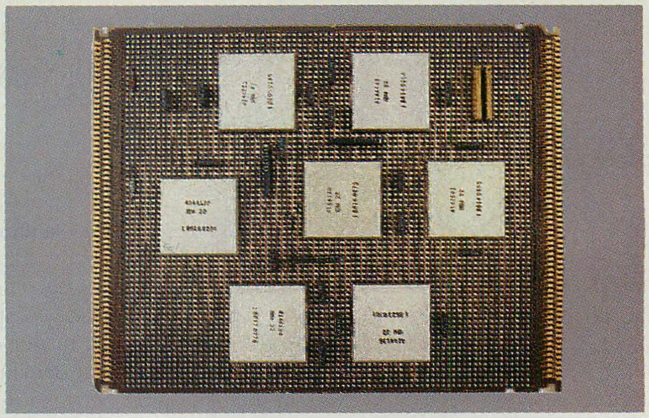

PHOTO 5: *8MB Memory Card*

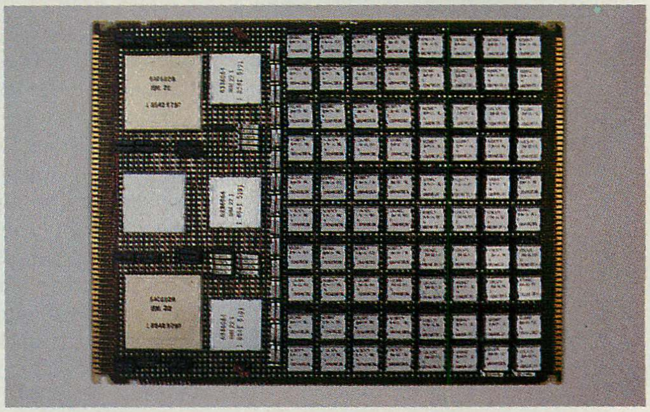

TABLE 1: *IBM System/370 Architecture Features*

FEATURE	9370	4381	3090
S/370 instruction set	●	●	●
Hardware floating-point arithmetic	●	●	●
Dynamic address translation	●	●	●
Extended architecture (XA)	○	◓	●
System/370 channel subsystem	◓	◓	●
Vector facility	○	○	●
Built-in communications adapters	●	◓	○
Multiprocessing	○	◓	●
Shared DASD	◓	●	●
Integrated disk and tape drives	●	○	○

● = *Fully supported*
◓ = *Supported, but with limitations*
○ = *Not supported*

The 9370 has a rich subset of the System/370 architecture, omitting only a few features, such as Extended Architecture (XA) and tightly coupled multiprocessing.

ambient air cooling, IBM's one-million-bit memory chip technology, and high-density logic circuits. Physically much smaller than other S/370s, they can be located in normal office space. The Model 20 is the size of a small file cabinet, needs no special air conditioning, and can be plugged into a standard wall outlet. Models 40, 60, and 90 offer an upgrade path that improves five-fold on the performance of the Model 20, which cannot be upgraded. Rack-mounted disk units, tape drives, and communications controller boards are interchangeable among all models (see photos 1, 2, and 3).

The primary operating system for the 9370 is the Virtual Machine/Integrated System (VM/IS). IX/370, an IBM adaptation of AT&T's UNIX, can be executed under VM/IS. Virtual Storage Extended/System Product (VSE/SP) and Multiple Virtual Storages (MVS/370) are possible alternative operating systems. Practically any systems or applications software that executes under these operating systems will run on the 9370. IBM announced a four-tier software pricing scheme, based on the type of CPU, to further reduce the cost of acquiring a 9370 system. IBM claims that the top-of-the-line Model 90 can support 70 to 145 concurrent VM users running a typical applications development or office systems workload, with a two-second response time. Models 20 and 40 can support 15 to 30 users under similar conditions.

IBM has partitioned its S/370 architecture into three tiers: 3090, 4381, and 9370. The most important distinction among these tiers are capacity (sometimes expressed in millions of instructions per second, or MIPS) and total system hardware cost: the 3090, at 7 to 75 MIPS, runs $2 million to $20 million; the 4381, at 3 to 10 MIPS, runs $500,000 to $2 million; and the 9370, at .5 to 3 MIPS, runs $70,000 to $400,000.

However, because MIPS statistics are notoriously unreliable, IBM does not publish performance ratings in terms of MIPS. The above ratings are derived from independent benchmarks, which may not represent any particular customer's workload. Specific system configurations can be more or less expensive. In practice, the initial cost of the smallest 9370 system is significantly higher than $70,000; this price is for a minimum hardware configuration and no software. Peripherals, memory, and software are expensive.

The 9370 clearly is *not* intended for a small business or the first-time computer user—it is far too expensive, and most S/370 applications software is not designed for small businesses. IBM offers three other computer lines for small business use: System/36, System/38, and Personal System/2. All have mutually incompatible instruction sets and I/O architectures. The System/38 compares in capacity and cost to the 9370, but has a radically different (and relatively advanced) architecture. The System/36 has a limited architecture with lower capacity at a lower cost. It is marketed as an entry-level small business computer.

ARCHITECTURE

Architecture is the key to the technical and marketing issues surrounding the 9370. The S/370 architecture defines what the product can and cannot do. Once it is understood, some important implementation details emerge as major issues. IBM implemented a subset of the architecture, and intentionally omitted a few well-known features. This subset is useful; it clearly reduced development time and cost for IBM, but will not materially affect the typical customer, at least in the short term (see table 1).

S/370 architecture defines the boundary between the processor logic (both hard-wired and microcoded) and the software executed on a machine, including the operating system. This can be equated to the instruction set of the processor plus the interface between software and all I/O devices attached to the system. Current product lines that support the architecture include the 3090, 4381, and 9370.

S/370 defines the architecture of the following obsolete products: the large 3081, 3083, and 3084 systems (very similar to 3090); the medium-scale 4321, 4331, 4341, and 4361 systems; the large 3031, 3032, and 3033 systems (introduced in 1976); and S/370 models 115 through 195 (announced in 1970). The S/370 architecture is upwardly compatible with the System/360 architecture. The announcement of System/360 in 1964 was a landmark event, which rendered obsolete all the computer technology of the 1950s and early 1960s, and effectively shaped the mainframe environment of today. Virtually all modern IBM large system hardware and operating systems, including the 9370, trace their heritage to this common root.

The CPU performs all processing and control functions of S/370. Most modern implementations of the architecture involve extensive use of microcode to perform the relatively large instruction repertoire. The CPU provides facilities for addressing real and virtual storage, moving data between storage and registers, arithmetic and logical processing of data, executing instructions in a desired sequence, and initiating I/O operations.

The basic word size in S/370 is 32 bits, but binary arithmetic can be carried out to 64-bit precision, and floating-point representations can be up to 128 bits long. The system provides 16 general purpose registers and 4 floating-point registers. The general purpose registers are used primarily for binary arithmetic, addressing and logical operations. Sixteen control registers are provided for operating system use only (for example, to support memory protection). The CPU has an interruption handling function that allows it to respond efficiently to asyn-

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chronous events including I/O, virtual memory management, programming errors and hardware malfunctions.

Processor storage can be configured in a variety of sizes, up to the 16MB architectural limit. Programs use a 24-bit address, which allows access to 16MB of address space. In the early 1980s, this became a limiting factor to performance for very large systems. IBM developed 370 extended architecture (XA), which raised the upper limit to 31 bits, or 2 GB. XA is supported on the 3090 and 4381, but not on the 9370.

Performance of the main storage subsystem depends upon many factors, including storage size, access width, cycle time, high-speed buffer (HSB) size, and program characteristics. *Access width* is the number of bytes transferred between the processor and main memory in each access. As access width increases, the quantity of data that can be transferred per second increases. In S/370, access width ranges from 2 to 16 bytes; in the 9370 series, access width is 4 bytes, except in the Model 90, which supports 8 bytes. *Cycle time* is a measure of the storage speed and is defined as the length of time that main storage is busy when a reference is made to it. IBM has provided no specifications for storage cycle time of the 9370, but IBM's 1-megabit storage chips are rated faster than 100 nanoseconds (ns). The basic machine cycle time (not necessarily equal to the storage cycle time) is 90 ns for the lower models and 50 ns for the Model 90. The *high-speed buffer* (called a *cache* by other vendors) contains recently used portions of processor storage, enabling faster access. HSB storage is 16KB on the Models 60 and 90; it is not used on other 9370 models.

Virtual storage permits users to write programs with the assumption that the system has multiple address spaces, each with as much as 16MB of storage. The total amount of virtual storage used by programs may exceed the amount of real storage on the system. This capability is provided by dynamic address translation (DAT) and channel indirect data addressing. These hardware functions are supplemented by operating system software functions. Virtual storage is structured into two levels: *segments* and *pages*. An address space is divided into segments of either 64KB or 1MB. Segments are divided into pages of 4,096 bytes (2,048-byte pages are possible, but seldom are used). A page may contain instructions, data, or both. When a program is exe-

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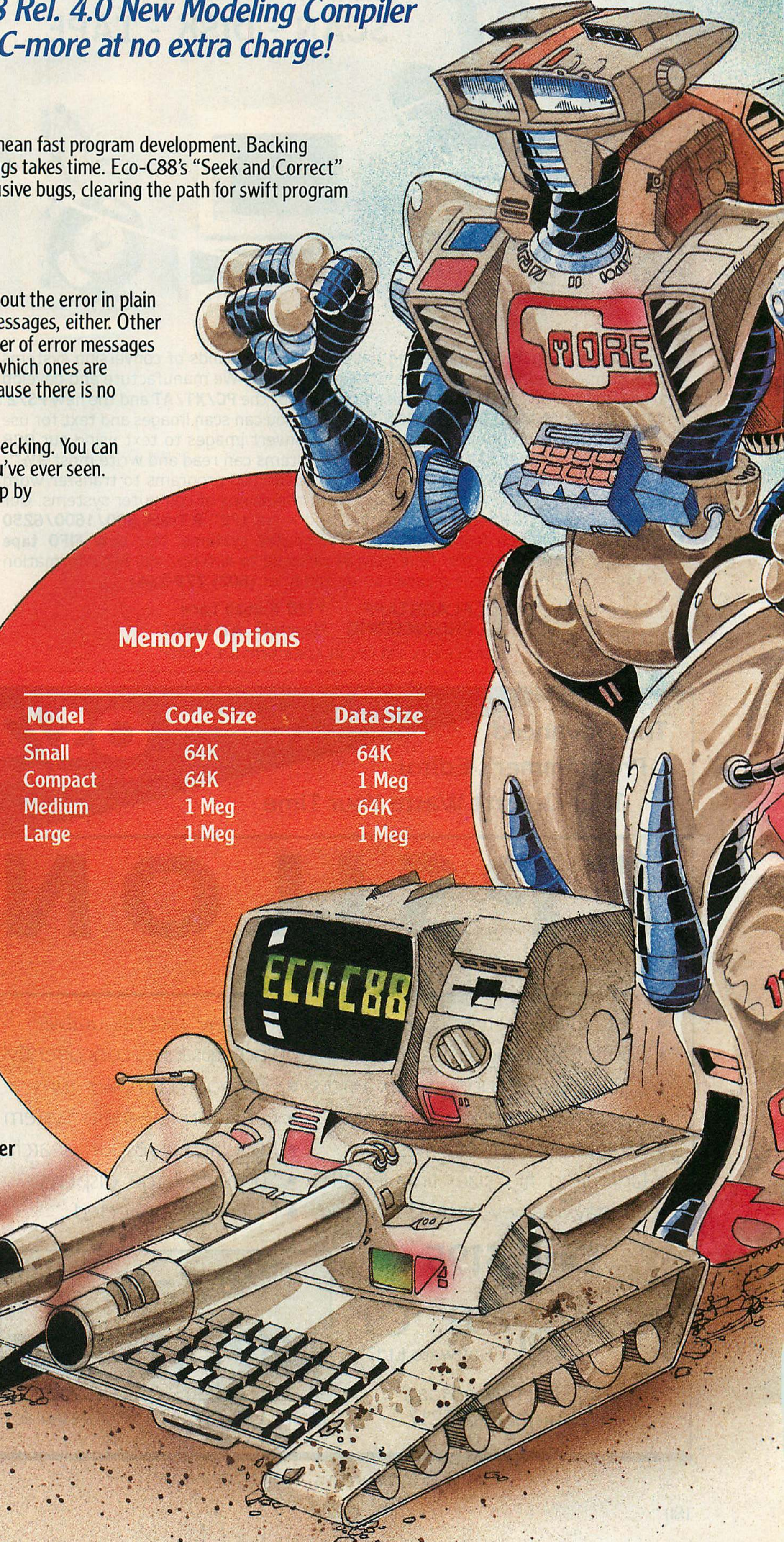

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cuted, the addresses of the program are translated from virtual to real addresses by the DAT hardware function. As pages of virtual storage are accessed, they are brought into real storage from external page storage disks by the operating system.

I/O operations transfer data between main storage and an I/O device. An I/O operation is initiated by a start I/O (SIO) instruction, which generates a command to a channel. A control unit receives the command via the I/O interface, decodes it, and starts the I/O device. Channels are the direct controllers of I/O devices and control units. Usually, control units are packaged separately from the CPU and connected by pairs of fat "bus-and-tag" cables that are routed beneath raised floors. These cables implement a standardized eight-bit parallel interface that is identical for all S/370 channels and control unit types. Cabling from the control unit to the device is not standardized, and varies substantially among products.

The 9370 represents a major departure from traditional S/370 in the areas of channels, control units, and cabling. While it is still possible to have separate control units and devices connected via bus-and-tag cables, it is no longer necessary. Disk and tape drives and controllers can be rack-mounted in the 9370's cabinet, and the *controller* connects directly to the system bus, which uses a proprietary interface unique to this product. (The disk and tape drive interface to the controller is EIA IPI-3, a published standard.) Communications adapters are attached in a similar manner. Interestingly, the 9370 bus can operate faster than 5MB per second, and thus is faster than an S/370 channel. This approach allows the product to connect to most standard S/370 peripherals, but also permits attachment of simpler, more compact and economical peripherals.

Channels can be viewed as specialized processors for I/O: they allow S/370 to read, write, and compute in parallel by relieving the CPU of the task of communicating with I/O devices. In some 370 machines, channels are physically separate from the CPU, but the trend is toward integrated channels that reside in the same box as the processor. S/370 has two types of multiplexer channel: *block* and *byte*.

A block multiplexer channel performs several I/O operations simultaneously, but transfers data to one device at a time, in burst mode. Burst mode allows an entire block of data to be transmitted in one operation, in a sin-

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gle logical connection to the device. It is intended for high-performance devices including modern disk and tape drives. A byte multiplexer channel transfers data to several devices at the same time, but it transmits one byte at a time. It is used for low-speed, unbuffered devices such as card readers or certain older adapters. Block multiplexer channels can be used on the 9370, but byte multiplexers cannot.

In theory, any channel can be connected to a maximum of 256 devices, but in practice, the number of devices is limited by workload and by channel data rates. Byte multiplexer channels operate at 50KB/second or less, and block multiplexers are limited to 3.0MB/second in current products. Architecturally, as many as 16 channels can be attached to each CPU, but some processor models support fewer channels. The 9370 Model 20 can be configured with a maximum of 4 channels; all other models allow 16. With XA, as many as 256 channels can be attached; however, no current IBM product supports that number of channels.

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Multiple S/370 processors can be locally connected using a configuration technique called *shared DASD*, or shared direct access storage devices, or, more simply, disks. With shared DASD, each processor is cabled to shared disk control units. Each DASD unit connected to the shared control units can be accessed by any CPU. The hardware provides locking facilities (called reserve and release) to protect the integrity of data. Only one lock is implemented per unit, so hardware locking at the file or record level is not possible. This degrades both performance and reliability, and various schemes in software and hardware have been developed to minimize its overhead. Nevertheless, shared DASD is commonplace because few efficient alternatives are available for sharing data at high speeds between different S/370 models.

The channel-to-channel adapter (CTCA) is another mechanism used to connect two S/370s at high speeds over short distances. As its name implies, the CTCA effectively connects two block multiplexer channels together, and each system appears as an I/O device to the other. The bandwidth of this connection is limited to the maximum channel data rate. Multiple CTCAs can be attached to a processor, if necessary. The distance between processors is limited to 120 meters, but it can be extended to 2 kilometers, at lower speed, by using an IBM 3044 fiberoptic channel extender. CTCAs often are used in conjunction with shared DASD and communications software such as the ACF/VTAM (advanced communication function/virtual telecommunications access method).

Multiprocessing, which refers to a system with two or more CPUs that share access to main storage, is sometimes called *tightly coupled multiprocessing*. It offers significant advantages over shared DASD:

- The workload balance among the CPUs is excellent. A single copy of the operating system resides in shared memory and dispatches user tasks independently. With shared DASD, each CPU has an independent copy of the operating system.
- System availability can be improved. The system can continue to process the workload while the CPUs, storage, channels, control units, and I/O devices are being repaired.
- Applications need not be aware that the system is a multiprocessor. Operating systems create the illusion of a single processor system, or *single system image*. Shared DASD requires a

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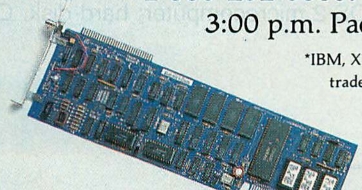

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large amount of planning by programmers and installation managers to operate efficiently.

Several of these multiprocessor configurations are possible:

- *Multiprocessor* (MP) contains two identical tightly coupled CPUs that can be separated into independent systems, as necessary. The 3033MP is an example of this type.
- *Dyadic* configurations contain two equal processors in one physical box, with a shared channel subsystem and shared memory. They execute one operating system and cannot be separated. However, if one CPU fails, system operation continues on the remaining CPU. Concurrent maintenance is possible. The IBM 3090-200E and 3081 are dyadic.
- *Four-way* processors (or "quads") are two dyadic systems connected in an MP configuration. Four CPUs share memory, channel subsystems, and one operating system or are separated into two dyadic systems running two operating systems. The 3090-400E uses this configuration.
- *Three-way* and *six-way* processors are also additional variations of the dyadic and quad concepts.

Multiprocessing and shared DASD have become so commonplace that single CPU environments seem somewhat unusual. Architecturally, the 9370 supports shared DASD and CTCAs. These features would be useful to connect a 9370 into a complex of existing large systems, for example, 4381s. However, it would be expensive and clumsy to connect two 9370s together using these techniques. Multiprocessing is not supported, but users are likely to demand it in the future, if only to ease the pains of system expansion.

In the early 1980s, IBM customers began to reach the limits of S/370 architecture in two important areas: addressing and I/O. IBM introduced S/370 XA to facilitate the implementation of very large systems. Two addressing modes are defined: 24-bit and 31-bit. This allows selective expansion of the address space to 2GB, but enables older programs to continue operating in 24-bit mode. IBM enhanced channel performance by moving portions of the I/O scheduling function from the operating system to microcode in the channel subsystem. XA redefines all I/O instructions and I/O path management functions of the operating system. To use XA, a customer must migrate to a new version of the MVS or VM operating system. XA is supported only on the 3081, 3083, 3084, 3090, and 4381 processors, not on the 9370.

A HARDWARE BLEND

The 9370 hardware design is a blend of new technology with concepts developed for the 4300 and 3090 series. The initial impression is of a serious, well-designed machine that will offer the customer outstanding reliability for many years. On the other hand, it represents no striking breakthroughs in technology or price/performance. It is simply a major refinement and partial redefinition of its immediate predecessor, the 4361. It renders the 4361 totally obsolete, but is not powerful enough to replace the aging 4381, which continues to be marketed.

Compared with older systems, the hardware of the 9370 is substantially repackaged. System functions are organized into discrete units—building blocks that contain the instruction processor, main memory, and I/O subsystem controllers within the processor package. Memory and logic chips are mounted on modules which are, in turn, mounted on cards (see figure 1).

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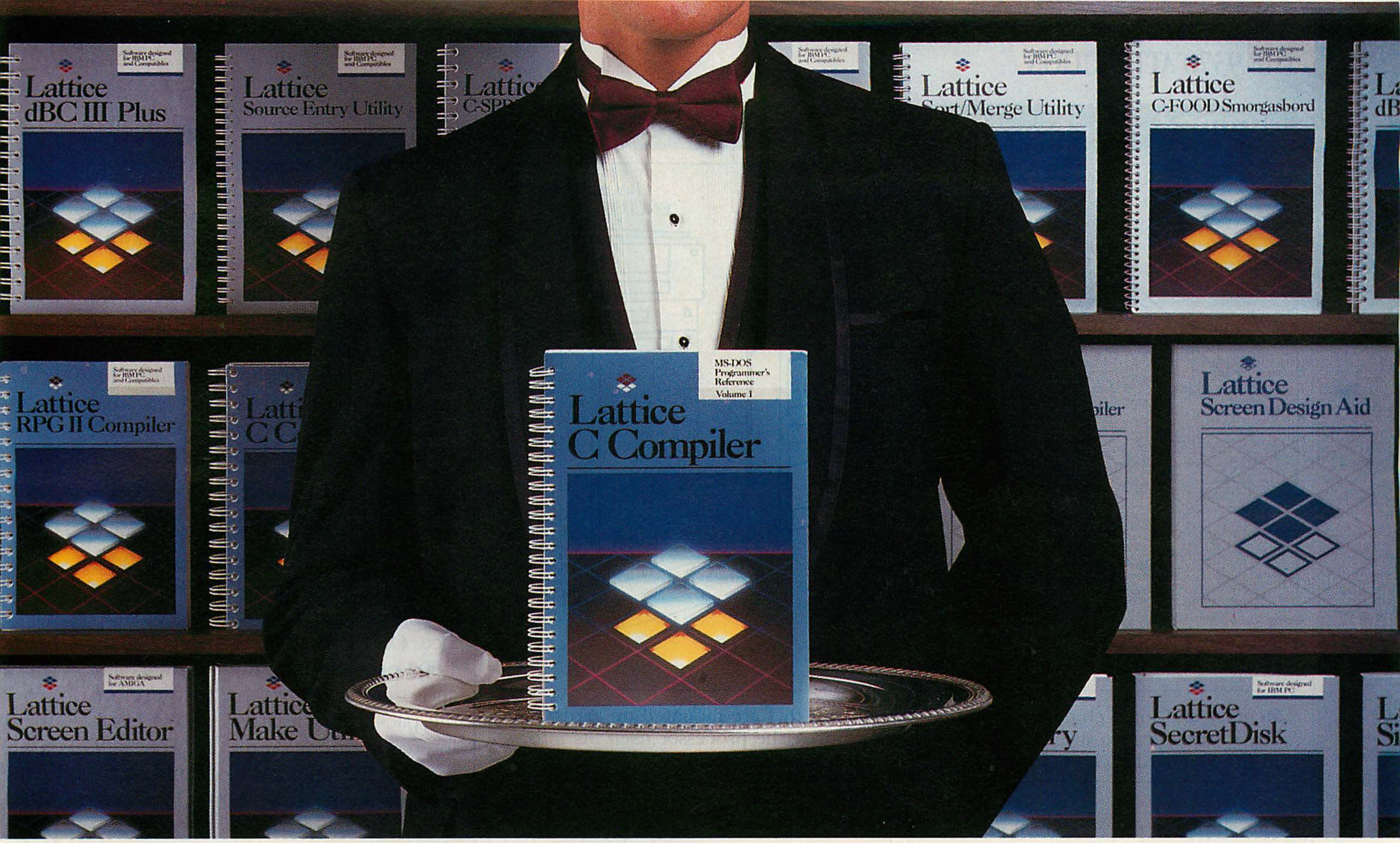

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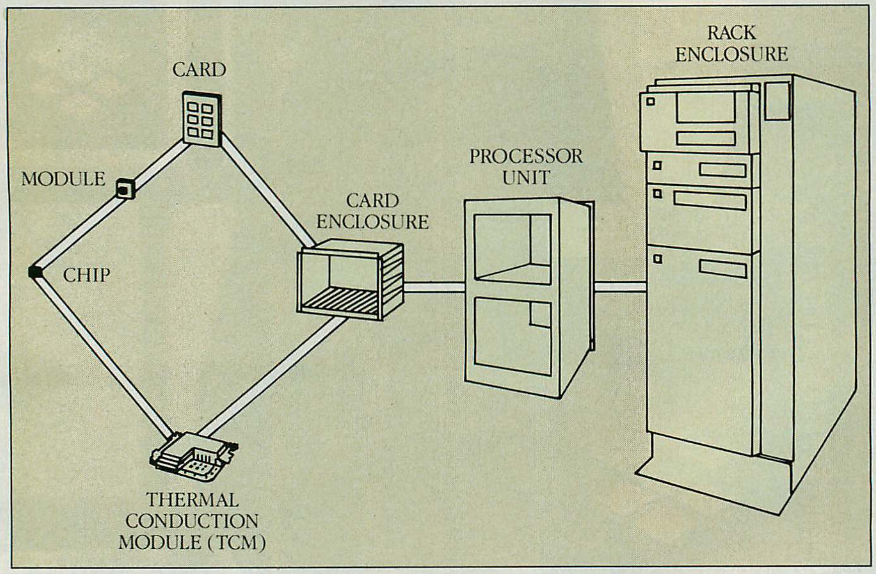
FIGURE 1: ***Hardware Packaging***



Memory and logic chips are mounted on modules that are mounted on cards. These cards fit into the processor's card enclosures; the processor itself fits into an EIA standard rack enclosure along with various peripheral devices.

Logic chips for the Model 90 are mounted on the multilayer substrate of an air-cooled thermal conduction module (TCM). Memory and logic cards fit into slots in the processor, which itself fits into an EIA standard rack enclosure along with DASD and tape devices. The rack is 1.0 or 1.6 meters high, and features a foot that protrudes from the base of the rack to prevent tipping when any drawers containing DASD or tape units are pulled out.

The system console/service processor, an IBM PS/2 Model 30, is connected to the system via two cables: an RS-232 cable to support processor control functions and a coaxial cable to emulate a 3278 display as a console. IBM provides software for the PS/2 to perform all system control and error logging functions. The service processor can be connected to a modem for remote operation, including powering the system on and off. Early shipments of the 9370 included a PC/AT, rather than a PS/2, but IBM representatives assured *PC Tech Journal* that production models would ship with a PS/2. Curiously, none of IBM's brochures mentions that the service processor is a PC- or PS/2-class machine.

The 9370 processors use a new generation of dense, high-speed bipolar logic chips. Chips used to implement processor logic functions provide more than 4,000 gates (see photo 4). Chips used in the floating-point accelerator card contain more than 7,500 gates. Two special types of memory chips provide fast access to frequently used data; both are static RAMs. One holds more than 9,000 bits and operates in a 25-ns access time. It is used as an HSB. The other static RAM stores the main memory addresses of all data in the HSB; this RAM holds more than 2,000 bits and operates at 16 ns.

Some of the logic cards used in the 9370 contain more than 40,000 circuits, and therefore represent some of the highest density packaging of any IBM system. The 9370 also includes dense memory packaging—up to 80 one-megabit dynamic RAMs are packaged on each of the system's 8MB processor storage cards (see photo 5). These cards contain a function that automatically selects redundant circuits and places them in service if a failure is detected. Memory and logic cards are enveloped by protective covers, which also direct the air flow across the cards for cooling. The card covers for the I/O controller cards include a tailgate assembly with connectors and support brackets in order to accommodate direct attachment of device cables at the rear of the unit.

The card enclosure in the 9370 represents state-of-the-art technology in card-on-board packaging. Two planar boards, at the top and bottom of the assembly, hold memory and logic cards inserted between them. A one-piece frame supports the two opposing boards and provides a mounting surface for fastening the package to the system frame. Cards slide freely into place and are secured by a retention spring on the card cover, before the Zero Insertion Force (ZIF) connector is engaged to provide the electrical connection to the 258 gold contact tabs on each end of the card. Each enclosure holds a maximum 17 memory and logic cards (see figure 2).

The Model 90 features IBM's first air-cooled TCM. Water-cooled TCM technology was first introduced in 1980 on the 3081, and has a good track record for reliability. A single TCM houses all processor logic, cache memory, and control storage for the Model 90. A total of 116 logic chips, each with 704 circuits, is used in this single large module. The TCM's substrate, with 33 layers, accommodates 3.2 meters of wiring per square centimeter of surface. On the bottom of the substrate, 1,800 pins supply power to the chips and route signals to the next level in the packaging hierarchy. All electrical interconnections on the TCM are made through the multilayer ceramic which contains more than 12,000 chip contact pads (see figure 3).

The 9370 product line includes DASD and tape devices plus I/O controller cards that can be added to the system incrementally. This reduces total system cost, as compared with older S/370 machines, in which control unit and I/O devices were separate standalone units. To add new devices, a customer need only open the back door of the system, insert an I/O controller card, and run a cable from the card to the I/O device. Inside the rack enclosure, clever cable holding arms help avoid a jumble of tangled cables. See table 2 for a list of the number and types of I/O controllers and the devices supported by each 9370 model. The following types of I/O devices are supported by the system:

- 9332 rack-mounted DASD, with 368MB drive and controller.
- 9335 rack-mounted DASD, with separate rack-mounted controller and 824MB drive.
- 9347 rack-mounted tape unit, which supports the standard .5-inch 2,400-foot reels of magnetic tape, with an integrated controller. Communications processor and multiprotocol adapter cards.
- Cards to connect 3270 workstations, ASCII/asynchronous terminals, IBM Token-Ring LANs, and the IEEE 802.3 (Ethernet) LANs.
- S/370 block multiplexer channel cards. These allow connection of virtually any modern stand-alone S/370 control unit or I/O device.

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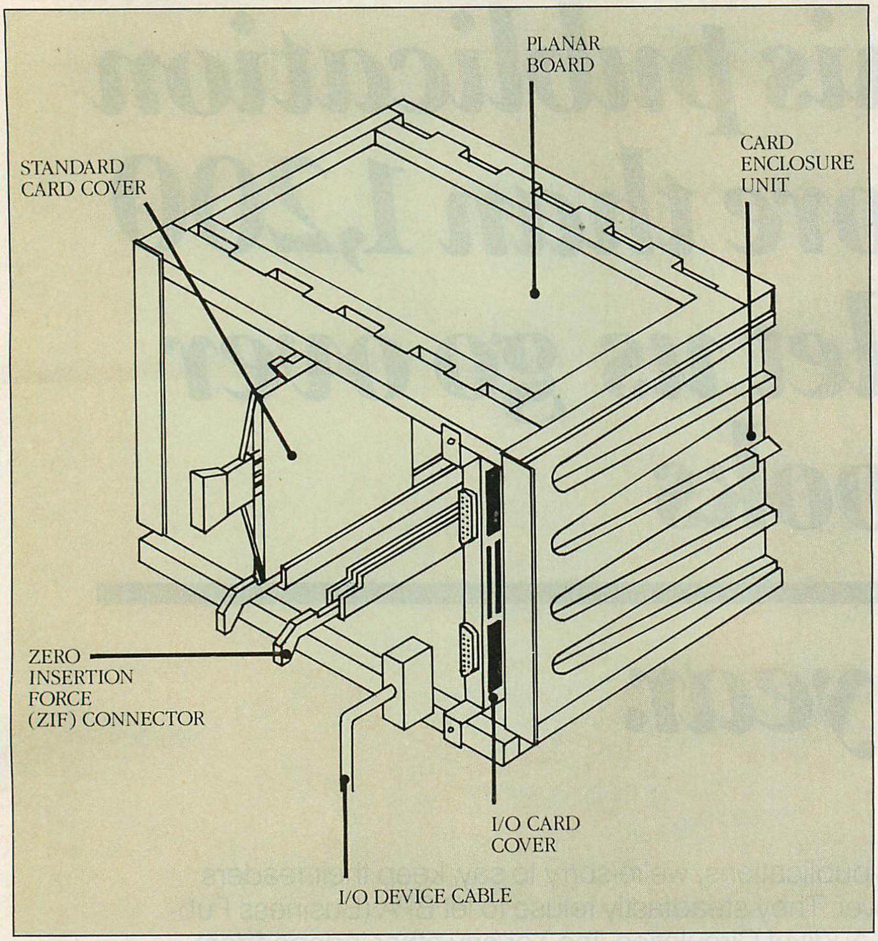
FIGURE 2: *Card Enclosure*



Cards slide freely into place and are secured by a retention spring on the card cover. The Zero Insertion Force (ZIF) connector is engaged to provide the electrical connection to the 258 gold contact tabs on each end of the card.

DASD specifications are somewhat comparable to IBM's far more expensive 3380 devices. They have about the same rotation speed and head movement time and therefore potentially the same access time on a lightly loaded system. Tape drive performance is inferior to its mainframe counterparts, but that is expected, given its small size and low price. Cartridge tape drives compatible with the successful IBM 3480 series are *not* available. The communications cards and terminal attachment features support a wide range of devices, at a lower cost than on a 4381 or 3090. See table 3 for pricing.

SOFTWARE SELECTIONS

Four operating systems are offered by IBM for the 9370: VM, VSE, MVS, and IX/370. VM seems the most suitable, considering the hardware and the system's most likely applications. It will run efficiently on all models, and it supports better scientific and office software than any other IBM operating system. VSE also is a good match for the hardware; however, it is fundamentally a batch operating system of 1960s vintage that has been given periodic face lifts over the years. MVS is clearly too large for the smallest 9370 models. It could be used on Models 60 and 90, but it would be rather expensive, in terms of both hardware and software. Finally, IX/370 is an IBM implementation of UNIX System V, which can run on any S/370 processor, but must be executed under VM.

VM is a general purpose operating system that offers excellent time-sharing facilities, limited transaction processing, and minimal batch processing facilities. VM's weaknesses are not as serious as they seem at first, because any other S/370 operating system can be executed in a virtual machine. The system is compatible with all current S/370 systems, including 3090, 4381, and 9370, as well as the PC/AT-370. It is the most versatile IBM operating system, and its popularity increases steadily. Several different VM products are available (IBM never offers just one of anything), but only two variations are likely to be encountered on the 9370: the Virtual Machine/System Product (VM/SP) and the VM/IS.

The difference between VM/SP and VM/IS is simply packaging; both provide the same basic operating system services. VM/SP is for purists—it comes from the factory with no additives. It is generated and installed in the traditional fashion by a professional systems programmer, who can tailor it to the installation's particular needs. Other software can be selectively added by the systems programmer. VM/IS is a pretested, ready-to-load, ready-to-use system that includes VM/SP plus popular end user software. VM/IS offers these modular optional applications:

- Text/Office Support (PROFS, DW/370, Application System)
- Intelligent Workstation Support (PC/VM BOND)
- Engineering/Scientific Program Development (FORTRAN, ISPF/PDF, and similar packages)
- Data Base Query (SQL/DS, QMF, and DBEDIT)
- APL Language Support
- Problem Solving Languages (BASIC and PASCAL)
- Networking Support (VTAM, RSCS, and NetView)
- Communications Controller Support (NCP, SSP, and EP)
- Remote Communication Support (CVIEW, PVM, and RSCS).

VM has two components—Control Program (CP) and Conversational Monitor System (CMS). CP manages resources of the system and creates virtual machines where operating systems can run. A virtual machine has software and simulated hardware resources that run in a real computer under VM. A virtual machine can do almost anything a real machine can do. Nearly all S/370 operating systems can run in a virtual machine, including MVS, VSE, and VM itself. On the 9370, VSE running under VM may prove a popular combination, as it was on the 4300 series.

CMS, which is designed to run in a virtual machine, cannot run on a real machine by itself—it requires CP. CMS lets the user run application programs from a terminal, and provides extensive facilities to manage files efficiently. The System Product Editor has full-screen editing capabilities for preparing text, data, and programs. The System Product Interpreter contains powerful command procedure and programming capabilities. CMS is structurally similar

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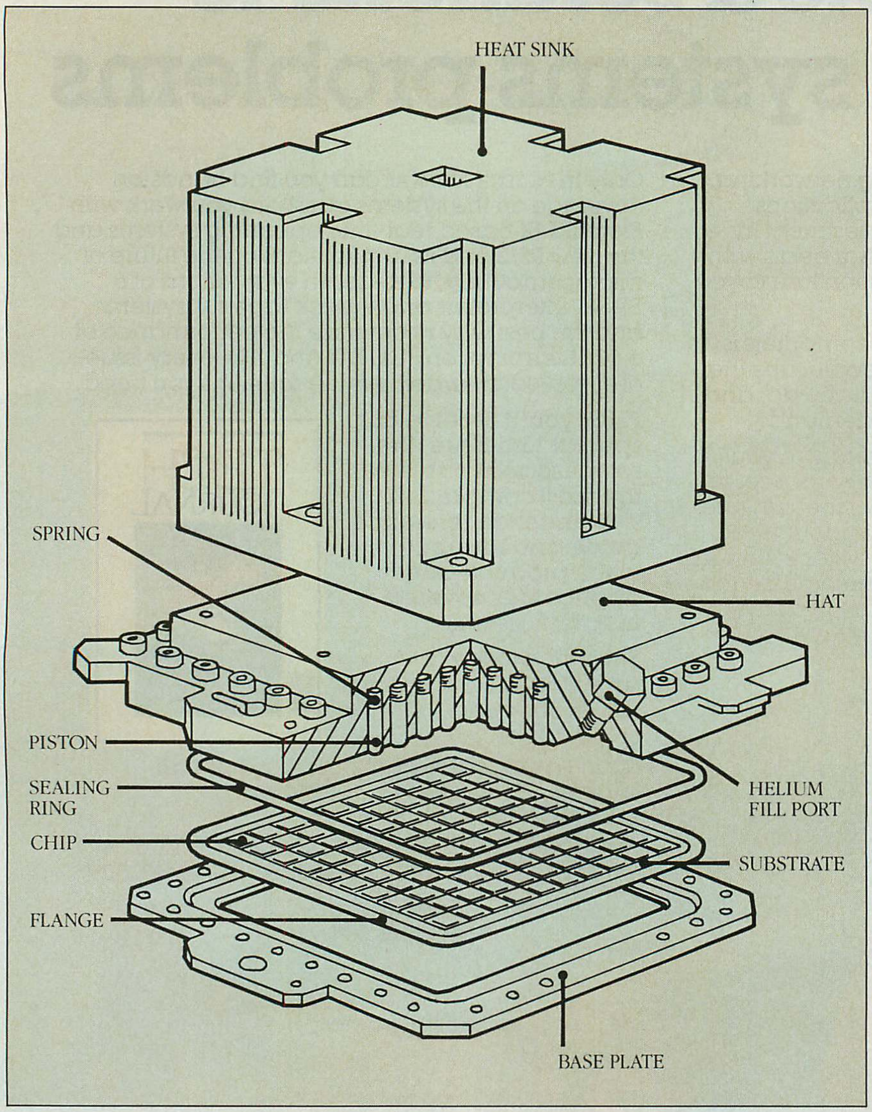
FIGURE 3: ***9370 Model 90 Processor***



The Model 90's 116 chips for processor logic, cache memory, and control storage are mounted on the multilayer substrate of a single, air-cooled Thermal Conduction Module (TCM), which is mounted in the lower part of the processor unit.

to DOS: it gives each user the illusion of having his own machine, and it has a command interpreter and system services comparable to those of DOS. The command language and programmer interface, on the other hand, are significantly different.

MVS, IBM's flagship operating system, was introduced in 1974 to control the largest IBM systems. Today it is intended for use on 3090 and 4381 systems. It is preferred by customers with heavy batch data and moderate transaction processing requirements. MVS supports batch, transaction, and time-sharing modes. It has excellent batch processing facilities, but its transaction processing functions and time-sharing facilities reflect the compromises inherent in a general-purpose system.

IBM offers two versions of MVS/SP: version 1 is called MVS/370 and provides multiple 16MB address spaces; version 2 is called MVS/XA, and supports XA. Version 1 can be executed on Models 60 and 90. Version 2 cannot be used on the 9370. The customer has a choice between two Job Entry Subsystems (JES), which mainly perform batch job scheduling and spooling. JES2 provides relatively simple job scheduling, and is chosen by a large majority of customers. JES3 is more sophisticated, has higher overhead, and is intended for very large complexes.

With MVS, customers execute batch jobs using the facilities of JES2 or JES3. Transaction processing is performed by a DB/DC software product such as CICS/VS (Customer Information Control System/Virtual Storage) or IMS/VS (Information Management System/Virtual Storage). Time sharing is provided by TSO (Time Sharing Option), a standard facility of MVS—it is not really an option. The TSO allows all terminal users to share remote access to the system for interactive processing. These include editing programs and data; compiling programs written in COBOL, FORTRAN, assembly language, and other popular languages; executing programs interactively; and submitting batch jobs and retrieving job output at a terminal.

Not all features of the 9370 are usable under MVS. For example, the 9335 and 9332 disk drives use a fixed-block architecture (FBA) format. MVS supports only count-key-data (CKD) DASD, such as the IBM 3380. Therefore, the block multiplexer channel feature and standard channel cables must be used to connect disk drives and control units to the 9370. The 9370's rack-mounted disks cannot be used with MVS, but they do operate with both the VM and VSE.

VSE/SP is an operating system that evolved from DOS/360, which is intended for small S/370 processors, including the 4300 and 9370. VSE is executed on more computers than VM and MVS combined, but the computers are relatively small mainframes. MVS and VM are far more important in a strategic sense, and some analysts suggest that IBM wants VSE customers to migrate to either VM or MVS.

VSE is a batch operating system, but it supports transaction processing and limited time sharing. It allows multiprogramming of user jobs and system services, including VSE/POWER (a spooling system), VSE/ICCF (a text editor, limited time sharing), CICS/VS (transaction processing), ACF/VTAM (communications software) and batch jobs. Users request services via the Job Control Language (JCL). The system supports a variety of high-level languages and file organizations.

Software written for the VSE environment is not directly compatible with MVS or VM/CMS and must be converted to run in those environments. Conversion is straightforward but time-consuming. VSE can be executed in a virtual machine under VM. This simplifies conversion and coexistence between the two systems. For many professionals, VSE is an intermediate step to a more sophisticated operating system such as VM or MVS. Sometimes it is used to supplement the weak batch processing capabilities of CMS.

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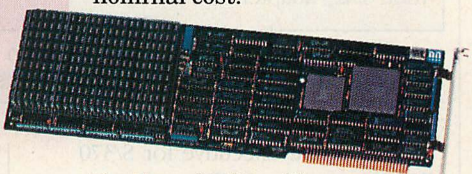

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TABLE 2: *System Capacities*

IBM 9370	MODEL 20 (9373)	MODEL 40 (9375)	MODEL 60 (9375)	MODEL 90 (9377)
Cycle time (ns)	90	90	90	50
Cache (MB)	N/A	N/A	16	16
Main memory (MB)	4/8/16	8/16	8/16	8/16
I/O capacity (MB/sec)	5.5	22	22	39
Data path width (bytes)	4	4	4	8
I/O buses	1	4	4	6
I/O controller slots	7	17	17	10-54
Total I/O subsystem controllers	4	16	16	16
Maximum of each type:				
DASD/tape	2	4	4	12
Workstation	2	6	6	12
Communications[a]	2	4	4	12
System/370 channel	1	2	2	12

[a] *Telecommunications, ASCII, IBM Token Ring, or IEEE 802.3 LAN*

The four 9370 models offer a wide range of capabilities and features, ranging from the Model 20 with its 7 I/O slots to the Model 90, with up to 54 I/O slots.

TABLE 3: *9370 System Pricing*

ITEM	MODEL/FEATURE	PRICE
9373 processor	020	$31,000
9375 processor	040	65,000
	060	93,000
9377 processor	090	190,000
Automated power controls	4000	800
4MB memory addition for 9373	4002	10,000
8MB memory addition for 9373 or 9375	4008	20,000
8MB memory addition for 9377	4108	20,000
I/O card unit adapter	5000	4,200
I/O card unit	5010	7,700
	5020	11,300
Channel power control	6001	1,600
S/370 block multiplexer channel	6003	6,000
DASD/tape controller	6010	3,000
Workstation controller	6020	4,200
Communications processor	6030	2,400
Multi-protocol adapter	6031	1,200
Asynchronous adapter	6032	825
IBM Token-Ring adapter	6034	1,950
IEEE 802.3 adapter	6035	2,700

Although all processors but the Model 90 are priced less than $100,000, total system price for a well-equipped midlevel system can easily exceed that mark.

Interactive Executive for S/370 (IX/370) provides UNIX applications execution, program development, and text processing environments for VM. Announced in 1985, it is faithful to AT&T's System V specification, with a few minor omissions (games and online documentation, for example), and a few IBM extensions, including virtual memory, file locking, performance improvements, a new editor, and intersystem communications facilities. The standard UNIX editors, command language, Bourne shell, communications support, and program development tools are available and have been integrated with VM. IX/370 cannot run in "native" mode (that is, a mode without VM) on an S/370 processor.

UNIX, in general, and IX/370, in particular, interface poorly to the S/370 environment. First, IX/370 supports only asynchronous terminals, not the ubiquitous IBM 3270s. On a traditional S/370, a Series/1 computer is required as a front-end processor for asynchronous terminal support; fortunately, this support is built into the 9370, so an external processor is not needed. Second, most of IBM's standard networking features, including Systems Network Architecture (SNA), are not implemented in IX/370 (see "SNA Strategies," Art Krumrey, July 1985, p. 40). Despite the fact that IX/370 shares common roots with IBM's other UNIX systems, such as AIX and XENIX, it is not fully consistent with them.

IX/370 seems doomed to be the least popular 9370 operating system. Because most UNIX applications are portable, there is no pressing need to run them on a S/370 processor—any architecture will do. IX/370 has not been used extensively on large S/370 processors, and nothing about the 9370 would make it particularly attractive to prospective UNIX users. Indeed, several other vendors offer more comprehensive support of UNIX than IBM, perhaps with less costly hardware. Furthermore, its poor integration with the IBM large systems environment makes IX/370 unattractive for the large corporate user who intends to build a homogeneous network. On the other hand, it may be useful for executing specialized applications in a VM system, where most other users are utilizing standard VM and CMS facilities.

NETWORKING

"Can it attach? . . . Yes it can!" says IBM in the glossy brochure that describes connectivity options for the 9370. Does IBM deliver on this crucial promise? Well, mostly. As usual, the "big picture" is littered with lots of fine print.

The S/370 architecture of the 9370 fully defines the product's networking potential. Virtually any networking feature available on the 4381 and 3090 can be implemented on the 9370. Many features can be implemented at reasonable cost, without a big investment in specialized hardware such as an IBM 3725 communications processors. The 9370 has all the architectural strengths and weaknesses of S/370, as they relate to networking. Generally speaking, the S/370 environment gives the user the widest range of IBM networking choices, although not necessarily the best for every conceivable application.

SNA sets the rules for communicating in an IBM computer network. It is the technical blueprint that partially defines most modern IBM communications products. IBM announced SNA in December 1973, and has been enhancing it steadily during the past 14 years. Originally the architecture connected

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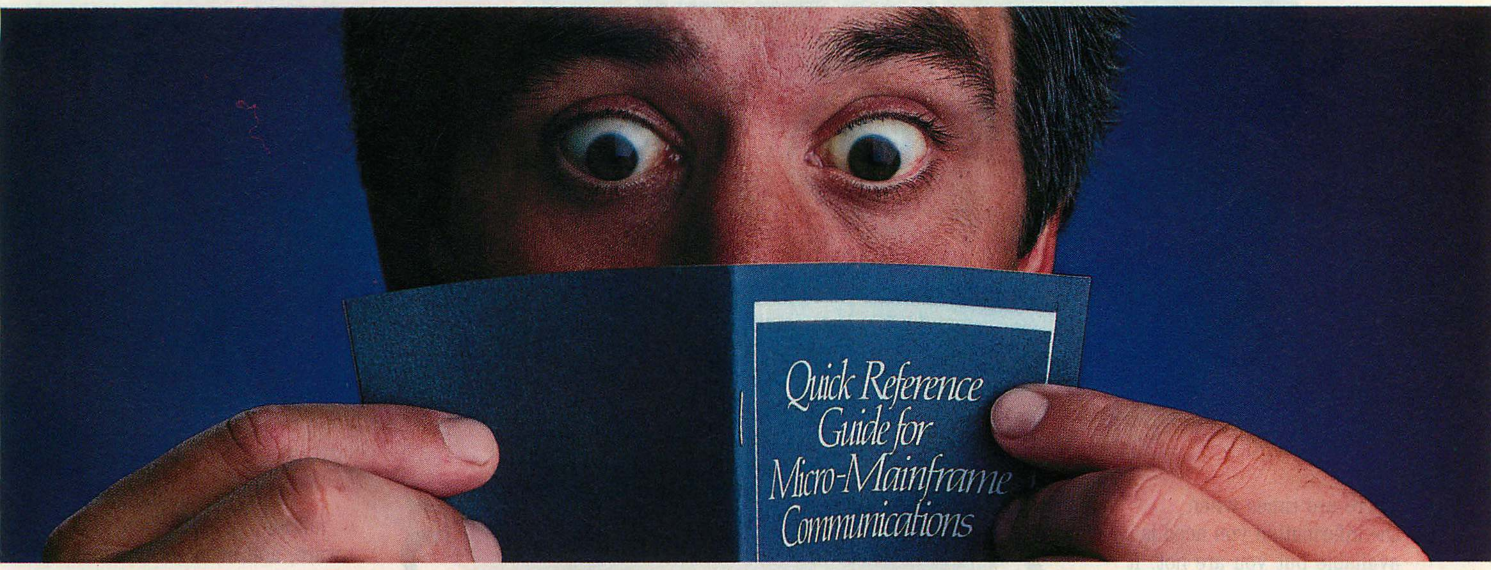

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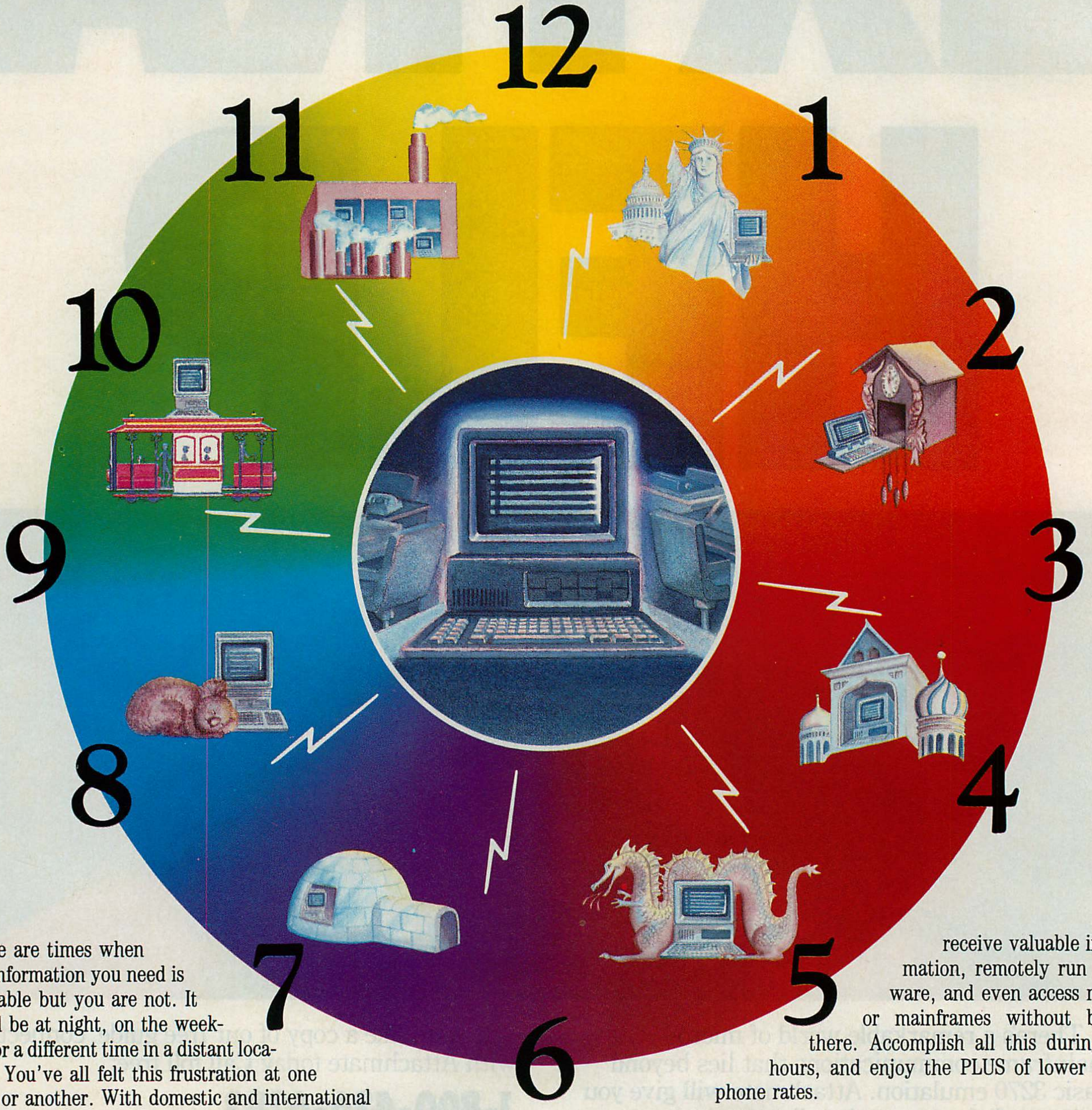

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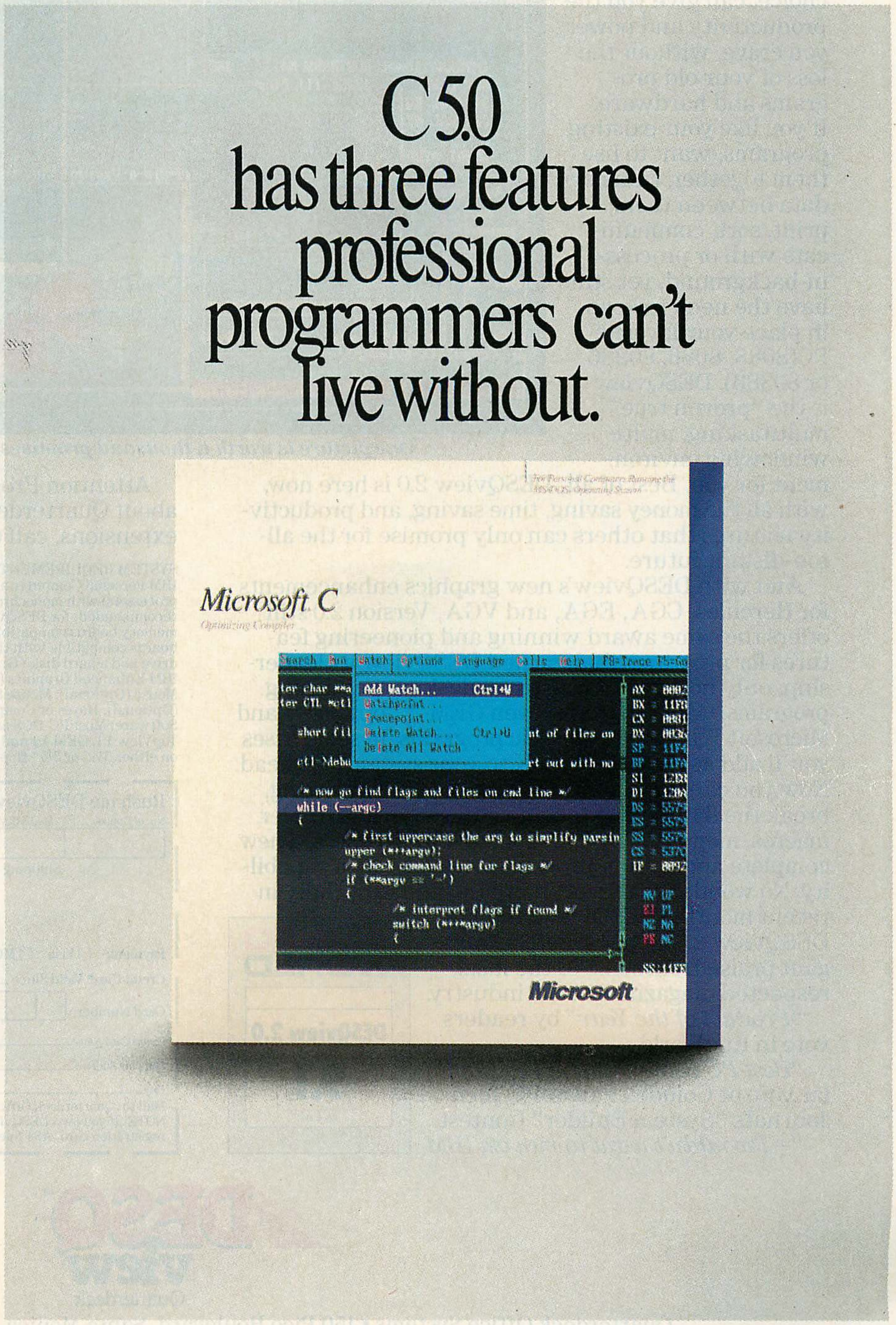
terminals to mainframe applications, but recently SNA has been restructured for direct communications between applications running on different computers in a network (see "Connectivity Pathways: APPC or NETBIOS," Michael Hurwicz, this issue, p. 156). During the 1970s, customer acceptance grew slowly. By 1980, a sufficient SNA hardware and software product set was available, and large corporate users rapidly implemented the technology. Today, more than 70 percent of the data links connected to large IBM systems in the United States use SNA protocols. The percentage is even higher in small IBM systems.

Customers expect a good SNA implementation on the 9370, and IBM delivers. SNA defines a hierarchy of nodes in a network, each assigned a type number (called physical unit, or PU, types): PU 1 is the terminal node for "dumb" terminals; PU 2 is the standard cluster controller (IBM 3174, 3274, or equivalent); PU 2.1 is the low-entry node—typically a System/36 or System/38; PU 4 is the communications processor (IBM 3720/25); and PU 5 is the host computer (S/370 or other).

Roughly speaking, the power and the complexity of a node increase with its type number (PU type 3 was never defined). The 9370 is a type 5 node, and it is viewed as a peer by all other S/370 host computers in the SNA network. Furthermore, the 9370 can act as a host to all other SNA node types. Terminals attached to the 9370 can use any application on any S/370 in the network, and terminals attached to other hosts can use any application on the 9370. In SNA terminology, the 9370 is called an MSNF host (Multiple Systems Networking Facility).

On a large S/370 processor, this is accomplished using a hierarchical arrangement involving several products. IBM 3270 terminals are connected by coaxial cable to a cluster controller (such as a 3174), which is connected using a data link (including modems, telephone lines, and so on) to a communications controller (3720 or 3725). Data links to other systems are attached to this controller. The communications controller can be programmed, so the customer must install IBM's Network Control Program (NCP) software. It is connected to the S/370 by a block multiplexer channel, using standard 370 channel cables. The customer installs one of the IBM operating systems, MVS, VM, or VSE, and adds IBM's Virtual Telecommunications Access Method (VTAM), which provides a large part of the host-based SNA network services. Applications are executed under CMS, CICS, TSO, IMS, or equivalent software, which must be installed separately. These products also provide SNA services, mainly acting as an interface between applications programs and the SNA network. This configuration is fairly complex, requires a high skill level to implement and maintain, and can be rather expensive.

The 9370 not only offers all the features described above, but it makes them simpler, more economical, and easier to implement. First, it is possible to implement the configuration exactly in the same manner as described above, although that would be costly. An IBM 3725, for example, can support as many as 255 data links and costs more than $100,000. It is likely that a customer would attach only a few data links to a 9370, so installing a communications processor that is more expensive than the CPU seems absurd. Thus, IBM offers a Telecommunications Subsystem Controller card, which provides most of the functions of the communi-



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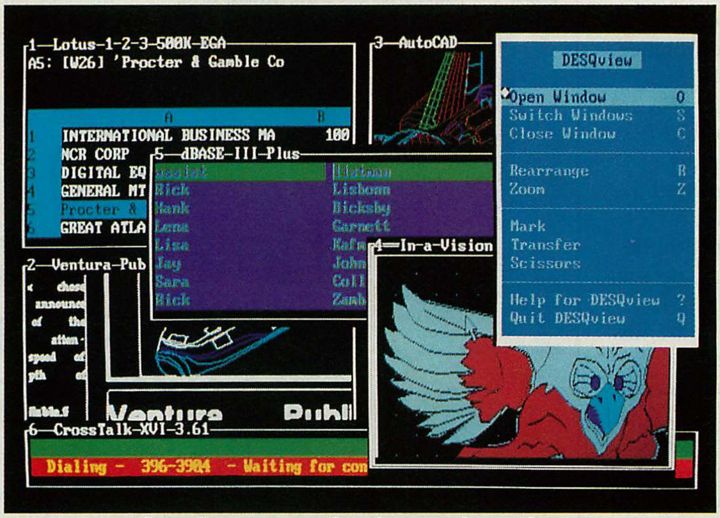

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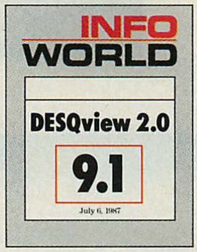

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cations controller at a small fraction of the cost. Nearly all communications links, both SNA and non-SNA, can be connected directly to the 9370, using one of the five types of communications cards, but without a separate communications controller.

The Workstation Subsystem Controller card is extremely useful. It attaches 3270 devices, including displays, printers, graphic devices, intelligent workstations, and personal computers directly to the processor. These are viewed as "local" devices, which usually are connected by coaxial cables and are subject to distance limitations of about two kilometers. IBM 3299 terminal multiplexers (fan-out boxes) allow attachment of more devices and reduce the total amount of cable required. The PC or PS/2 containing an IBM 3278/79 adapter card (or equivalent) and IBM's 3270 Emulation Program or 3270 Workstation Program are easily attached. Other well-known products, such as DCA's Irma, will also work. The Workstation Subsystem is equivalent to a S/370 equipped with a local IBM 3174 or 3274 cluster controller, and allows 3270 terminal and printer emulation, virtual disk, virtual print, and virtual file access to mainframe files using Enhanced Connectivity Facilities (ECF). (For more details, see "Emerging 3270 Coherence," Mary DeWolf, August 1987, p. 194.)

The ASCII Subsystem Controller supports many common types of asynchronous terminals, making them appear to the system as 3270 terminals. The UNIX terminal interface is supported for IX/370. Terminals or PCs can be connected directly, or via modem using the RS-232 interface. After a terminal connects, the controller displays a menu that requires the user to specify the type of asynchronous terminal being used. This product supports many popular terminals and printers including IBM 3101, 3161 through 3164, 3812, DEC VT100 and VT220, Epson FX-80 printers, and various ROLM, Tektronix, and TeleVideo products. PC users can emulate any of these. Although asynchronous terminals are not considered SNA devices, they can communicate with any SNA application on the network, because the ASCII subsystem controller and VTAM effectively perform protocol conversion.

The Telecommunications Subsystem Controller is extremely versatile in terms of communications protocols. SNA (SDLC), Binary Synchronous (bisynchronous), asynchronous, and X.25 (HDLC) protocols can be used. The communications processor provides most of the functions of the IBM 3725 on a single card. A telecommunications subsystem consists of:

- One communications processor (a maximum of twelve per CPU)
- One to three communications adapters (each with two or four lines)
- Microcode for the subsystem
- A communications network including various terminals.

The 9370 can be configured as a host and communicate with all attached terminals and other hosts. It can act as a remote terminal to another host system. Each communications processor operates at a maximum aggregate data rate of 76 kilobits per second (Kbps). The microcode for the processor is included; NCP software is *not* required.

IBM offers two types of communications adapters: asynchronous and multiprotocol. The multiprotocol communications adapter implements all the protocols listed above, including asynchronous, at speeds up to 64 Kbps. Two data links can be connected using any of the usual physical interfaces, in-

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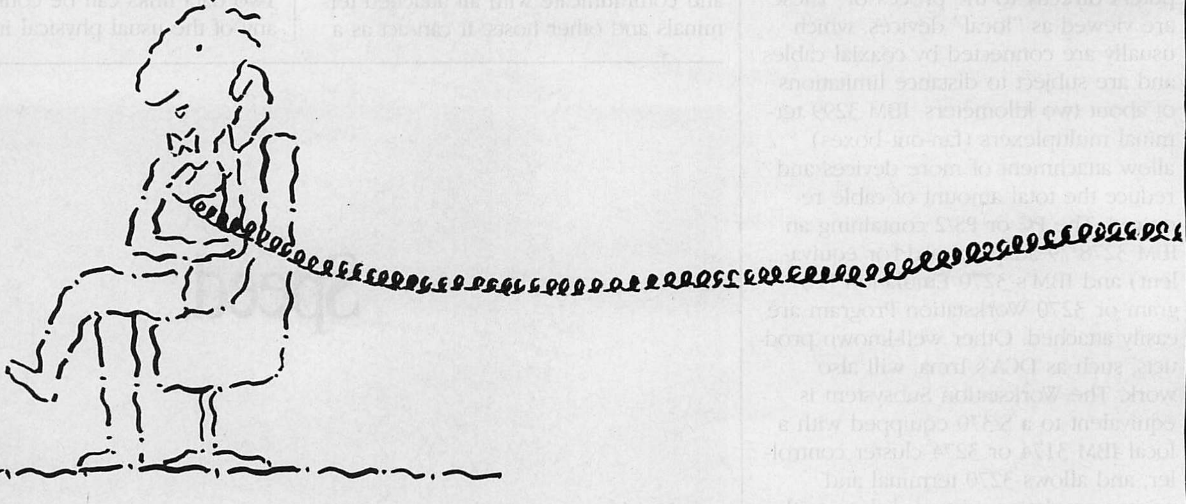

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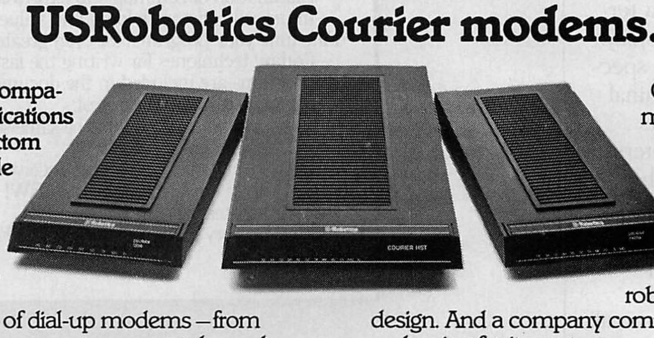

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- System/36, System/38, Series/1 acting as cluster controllers
- IBM 3725 or 3270 systems, connected to the S/370 hosts
- Other 9370 models
- X.25 packet data networks.

The asynchronous adapter connects four data links, each operating at up to 19,200 bits per second. Unlike the ASCII subsystem controller, the asynchronous adapter does not perform protocol conversion, and terminals do not appear as 3270 devices. Typically, such devices are treated as teletypes.

The 9370 is equipped for excellent connectivity to IBM SNA mainframe networks. The communications processor, plus a multiprotocol adapter, can provide a 64-Kbps pipeline from the 9370 to a big SNA network. The 9370 is viewed as a network host, with the same stature as a large S/370 processor. This is adequate for many applications, but if necessary, multiple independent 64-Kbps links can be implemented, using multiple communications processors, subject to hardware and architectural limits.

The telecommunications subsystem includes not only the latest SNA terminals, but many of IBM's older bisynchronous terminals as well. For many years, the SNA software for VM had serious structural deficiencies. Consequently, many VM users avoided implementing SNA and continued using bisync. In the past two years, IBM resolved the problem by delivering a workable SNA implementation for VM. Nevertheless, many bisynchronous and asynchronous terminals still are used with VM (and, to a lesser extent, MVS and VSE). Such terminals can be used on the 9370 in the same manner as they are used on the S/370 systems.

The IBM Token-Ring Subsystem Controller connects the 9370 to the IBM Token-Ring LAN. This network conforms to the IEEE 802.5 standard, uses a token-passing access technique, and operates at 4 megabits per second (Mbps) over shielded twisted-pair cable or certain telephone wire. (For more information, see three articles by J. Scott Haugdahl, "Underlying Connections," December 1986, p. 126, "The Token-Ring Solution," January 1987, p. 50, and "Token-Ring Network, Part 2," February 1987, p. 158.) The 9370 acts like a S/370 mainframe on the network. It communicates across the token ring using SNA host-to-host (MSNF) protocols with S/370s or other 9370s (software will be available late 1988). PCs or PS/2s access applications on the 9370 using SNA 3270 protocols. This requires the IBM PC 3270 Emulation Program, version 3.0, or the 3270 Workstation Program, version 1.1 in the PC. Workstation Subsystem Controller features are available through the IBM Token-Ring LAN.

3Com's Ethernet is supported by the IBM IEEE 802.3 Subsystem Controller. IEEE 802.3 defines a LAN access technique that employs collision detection, operating at 10 Mbps on coaxial cable. Transmission Control Protocol/Internet Protocol (TCP/IP) is used for the upper layers of the interface. It allows virtual terminal access and file transfer between the 9370 and other systems that support the TCP/IP. A virtual terminal appears as an IBM 3270. The TCP/IP is used in certain U.S. government installations, universities, and

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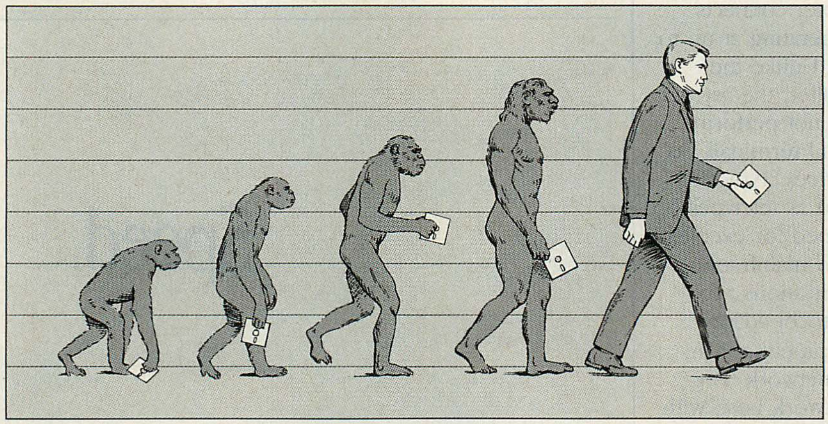

"In this competitive world, a difference of just 10% can mean the distinction between pinstripe and primate."

Many people don't realize that chimpanzees and humans share 90% of the same genes. A minor difference sometimes translates into major improvements.

Industry analysts predict that the LAN market will quadruple by 1990. Networks will get larger and will take on more serious tasks. As companies invest more capital into these systems, they are going to look for ways of guaranteeing performance and data integrity; in an environment as competitive as today's marketplace, even small mistakes can change the very nature of a business.

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What It Does

NetWare fault tolerance can be divided into two categories; software-based protection and hardware-based protection. Because Novell feels so strongly about the fundamental need for data protection, fault tolerance is included in all NetWare to some degree. Advanced NetWare 286 v2.1 contains features ensuring that files can be read after they are written, and redundant copies of directories are routinely made.

HOT FIX,™ another standard fault tolerance feature on the v2.1 release, detects disk media errors before data is sent to a flawed area. What might have been sent to a bad spot, then garbled, is saved to a designated "safe" spot by NetWare's HOT FIX feature.

SFT Level II fortifies system integrity further by adding hardware duplication. Level II backs up your system's entire hardware channel with another identical channel. Thus, if a component, such as the hard disk, fails on the main channel, the reserve automatically takes over operation. And no data is lost.

Level II also automatically copies all data to both hard disks, so that data can be recalled from the backup in case of any kind of recall problem on the original disk.

The TTS Option

SFT NetWare Level II also offers, as an option, the Transaction Tracking Service. TTS acts as a vanguard to database integrity by guaranteeing that all transactions are completed before allowing the application to advance.

For instance, if you are operating a database and the power goes out, bringing down your workstation, chances are you will get caught in the middle of a transaction. When you resume operation, you have to go back and find where you were, and hope that the database is still intact.

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Natural Selection

Offering such important benefits, it would seem that the SFT Level II operating system would be a natural selection for almost any business. Of course, not everyone is going to agree.

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other multiple vendor environments. It is available for the PC and in some implementations of UNIX. IEEE 802.3 also is supported by the IBM RT PC and the Series/1.

For very high speed connections from 9370s to S/370 systems, the block multiplexer channel card must be used. The card can be connected directly to an IBM 4381 CTCA, or via a IBM 3044 channel extender (which allows a two-kilometer fiberoptic cable, at lower speed) to any other large S/370 processor. Unfortunately, two 9370s cannot be connected directly using this technique, unless the connection is through an IBM 3088 Multisystem Channel Communication Unit. The CTCA operates at 1.5MB per second, and can be used with a variety of system software including VTAM (SNA communications) and JES3. The block multiplexer channel can be connected to the new IBM 3737, which is connected to public or private T1 communications facilities (1.544 Mbps, or one-eighth the speed of a CTCA). It has no distance limitations. Operation of the 3737 is identical to a CTCA; the 3737 also can be used between two 9370s or from a 9370 to a large S/370.

Given the 9370's LAN connectivity and high-performance disk subsystems, will it perform well as a file server with PCs? No. The product's LAN connectivity is designed primarily to promote 3270-style terminal connections and low-speed file transfer. The virtual disk concept mentioned above seems attractive, but it operates at a speed that makes diskette drives look fast. Furthermore, data must pass through many layers of S/370 software architecture, including a general purpose operating system, disk access methods, VTAM communications software, and applications subsystems such as CMS, TSO, or CICS, which do not exist in a dedicated file server. Despite the high overhead, file sharing with PCs is easy to do and useful for many applications. Just don't expect it to be fast.

FUTURE DIRECTIONS

In the next few years, there is no question that the 9370 will be enhanced in a variety of ways. While it is virtually impossible to predict accurately IBM's future moves, it is, nevertheless, interesting to speculate.

Two key areas of S/370 architecture are missing from the 9370: multiprocessing and XA. In the 4300 product line, IBM originally announced uniprocessor systems, and later offered multiprocessors at the top of the product line. Multiprocessing has been part of the S/370 sales pitch since the 1970s, and it is common in smaller IBM computer lines, including the System/36. A possible future development is a multiprocessor version of the Model 90. Then the 16MB memory limit of S/370 architecture will become a major performance bottleneck. (Incidentally, this may already be a problem with the Model 90, especially when running MVS). One solution is to implement extended architecture on the 9370, at least on the top models, which will allow up to 2GB of memory. Eventually, IBM will want to phase out pre-XA architecture and drop support of the associated operating systems.

Another missing piece is the S/370 computer on the desktop. Yes, the PC/AT-370 is around, but the PC/AT part is now dead. Regardless, the AT-370 was not really a serious product, but an interesting idea. It would be attractive to have a computer network that supports S/370 architecture from top to bottom. For years rumors have circulated that IBM has a 370 on a chip. IBM has

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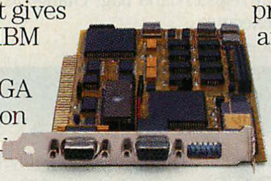

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stated that development work on the VM/PC operating system continues. What about hardware? Silence.

Considering its current collection of operating systems, IBM made the right choice by promoting VM as the primary operating system for the 9370. VM has excellent time-sharing facilities, but poor batch processing and no transaction processing. To effect transaction processing, a customer must install CICS under VSE or MVS running as a guest operating system under VM. VM/IS was not designed to handle this requirement easily. What is needed is a standard transaction-processing environment for VM that is compatible with CICS. IBM will likely continue to improve the batch- and transaction-processing support of VM, so that fewer customers will need to run VSE or MVS as a VM guest operating system.

Though the networking facilities of the 9370 are easier to implement than other S/370 systems, much room is left for improvement, and the competition, especially DEC, is far ahead. IBM will need to provide a better way of packaging and delivering network software, and must reduce the layers of overhead in communications system software. Currently, this makes it impractical to use the 9370 as a high-performance file server. IBM apparently was surprised that customers intended to use the 9370 as a host node in hierarchical SNA networks—the company assumed that the 9370 would be used in a peer-to-peer environment similar to System/36 and System/38. IBM will make SNA network implementation much simpler and more automatic. Support for the Token-Ring LAN will be extended to support a wider range of SNA protocols, and will allow efficient sharing of both mainframe files and databases with other machines. This sharing also will allow much better integration of PCs and PS/2s.

The fact that IBM included standard interfaces in the 9370, such as Ethernet, TCP/IP, and asynchronous terminals, indicates that the company has become more responsive to customer connectivity requirements. Other vendors offer far better integration with their competitors' network architectures. It seems likely that IBM will improve its integration with non-IBM networks, both by aggressively implementing official standards, and providing gateways to other popular architectures.

The initial announcement of the 9370 represents an important step forward from the previous generation of mid-sized S/370 computers. Although it has a few obvious faults, the 9370 is a very sound product that meets many specific customer requirements. The new product will be a valuable tool for implementing a multilevel computer network in a wide variety of organizations. The 9370 provides excellent, high-performance interfaces to S/370 systems. The 9370 also offers many approaches for PC integration, but none represents the ultimate. The primary function available through a PC connection, whether it is via coaxial cable, modem, or network, is 3270-style terminal emulation and low-speed file transfer. Much room has been left for improvement in its systems software and networking capabilities, and such improvements are very likely to be forthcoming. There should be little doubt that the 9370 will be successful, both financially and technically.

Dennis Linnell is president of Gate Technologies, Inc., a consulting and software development firm in McLean, Virginia. He specializes in the area of IBM Systems architecture.

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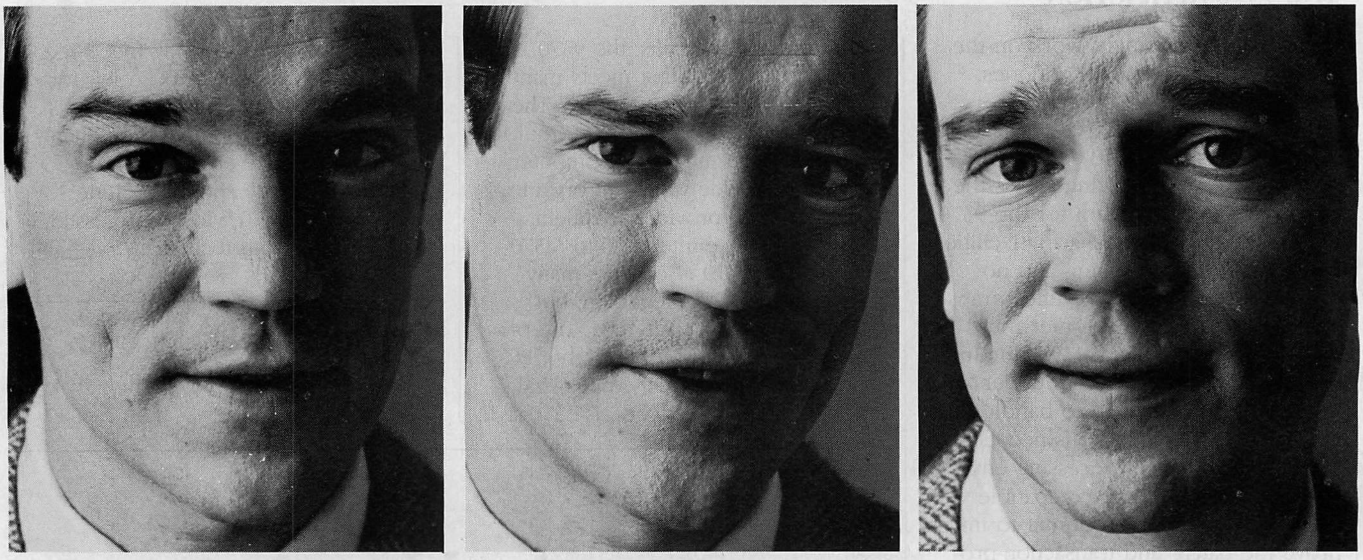
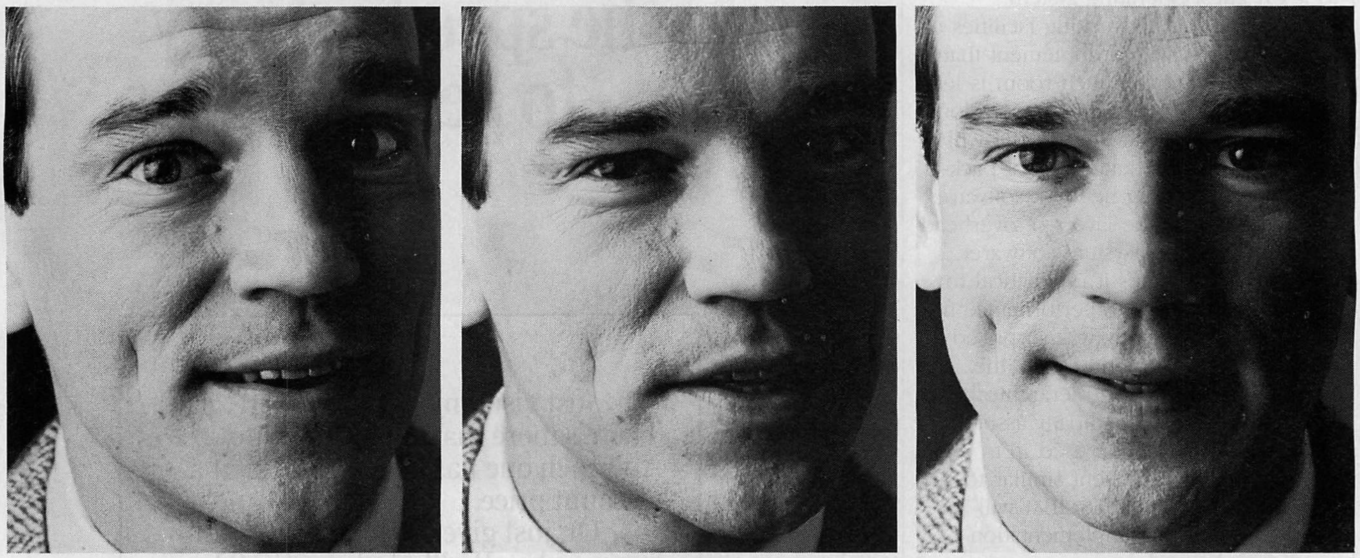
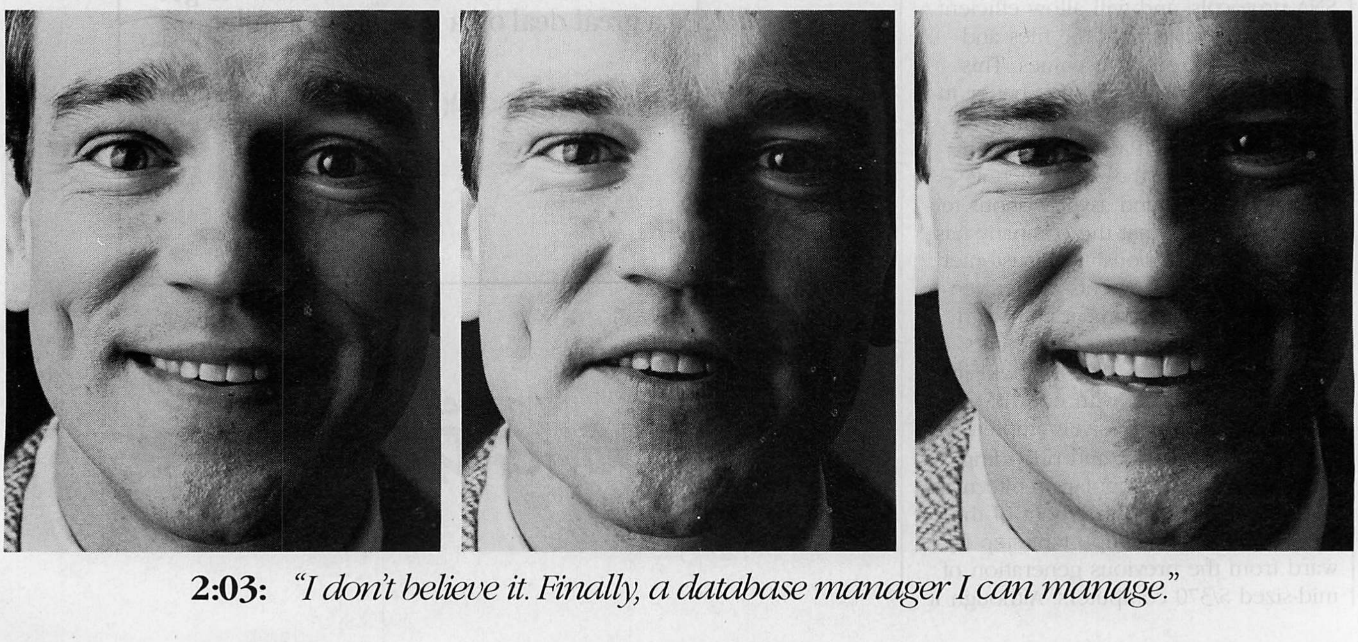


9:32: *"Another database manager? I couldn't get to first base with the last one."*



11:45: *"Okay, so forms are easy. I bet they'll zap me when I get to reports."*



2:03: *"I don't believe it. Finally, a database manager I can manage."*

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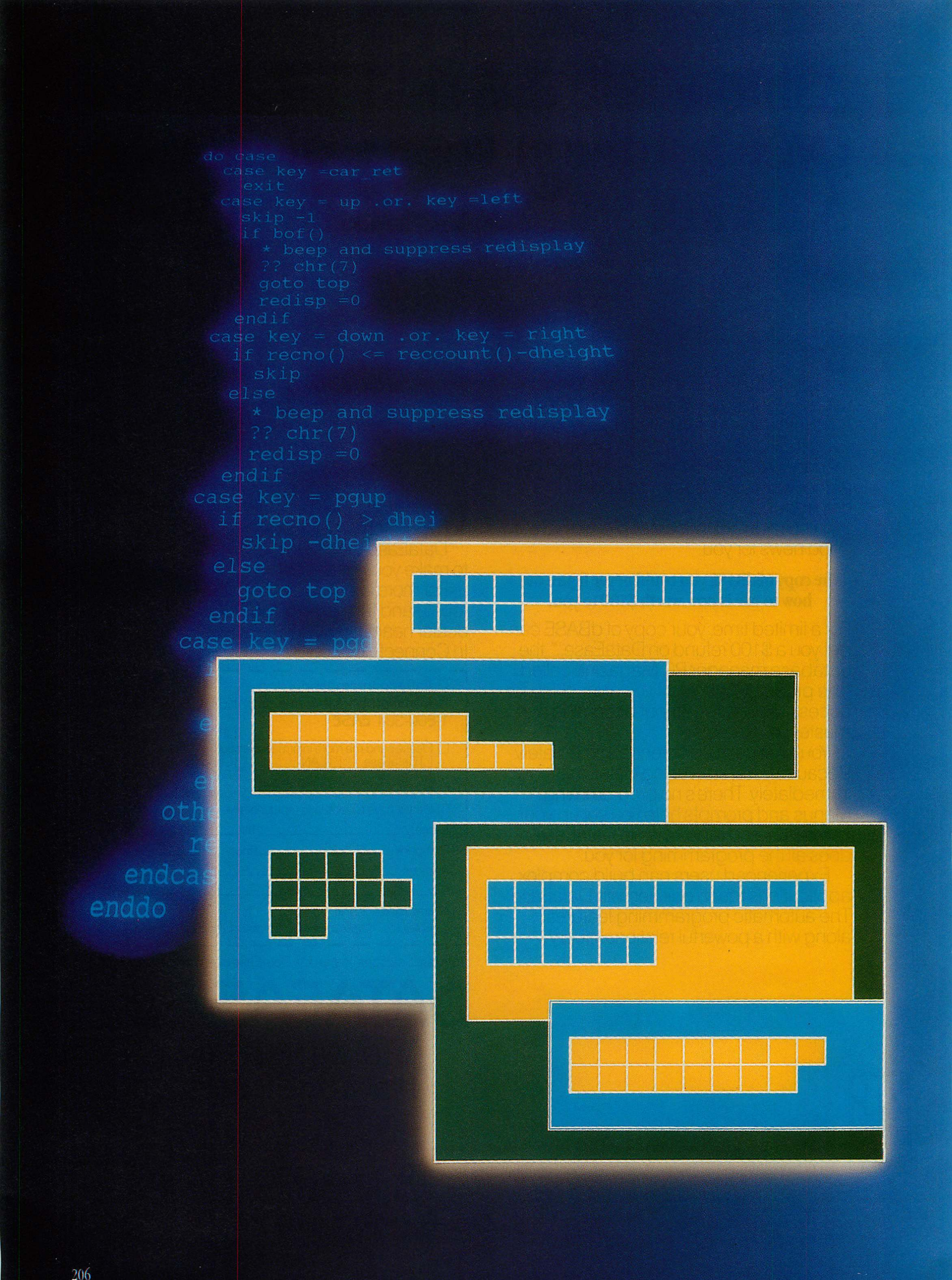

do case
case key =car_ret
exit
case key = up .or. key =left
skip -1
if bof()
* beep and suppress redisplay
?? chr(7)
goto top
redisp =0
endif
case key = down .or. key = right
if recno() <= reccount()-dheight
skip
else
* beep and suppress redisplay
?? chr(7)
redisp =0
endif
case key = pgup
else
goto top
endif
enddo

Interface Design

DAVE BROWNING

dBASE user interface screens can be generated using The UI Programmer from WallSoft Systems, Inc., which applies fourth-generation language techniques to help automate programming.

The ubiquitous dBASE from Ashton-Tate maintains its popularity as the leading language for database application development in the IBM PC environment in spite of shortcomings. Granted, the dBASE language contains command primitives that allow the programmer to create applications combining user-interface screens, multifile transaction processing, and predefined queries and reports; nevertheless, it is a laborious process to design, code, debug, and test most of these programs.

Besides lacking fully relational data management with a standard query language (SQL) interface, the dBASE language lacks functional power in three areas: user interface, report generation, and automated multifile manipulation. The UI Programmer from WallSoft Systems, Inc., addresses the first of these deficiencies, the user interface. It can be used with dBASE III and dBASE III PLUS, as well as with three popular dBASE dialects: Nantucket Corporation's Clipper, Fox Software, Inc.'s FoxBASE+, and WordTech System's Quicksilver. (For a review of these three dBASE dialects, see "Dialects of dBASE," Ted Mirecki, April 1987, p. 46.)

The UI Programmer brings fourth-generation language techniques to applications development in the dBASE data-management programming language. It helps implement automatic programming of user-interface screens and streamlines application coding. The UI Programmer mainly addresses processes that involve communication with the application end-user via the screen, but it also can be used to create code-generation tools for special-purpose repetitive operations.

The UI Programmer performs these functions by generating code; it accepts parameters from the user and creates dBASE program files. The primary characteristics that set UI apart from other code generators are that developers can write their own templates in addition to using those provided by the generator, can directly modify (using template language commands) the code that has already been generated and then generate a new program file using the old program as a template, and can specify code-generation parameters visually in terms of objects and object attributes on the computer screen. UI provides a tool with which the serious dBASE programmer can create a bag of tricks specific to his usual style of application development. It is also a code generator "engine" that less experienced dBASE programmers can use in combination with templates developed by others.

Every UI-generated program has to have a template as a model. A UI template file contains dBASE code and special text labels that are UI commands.

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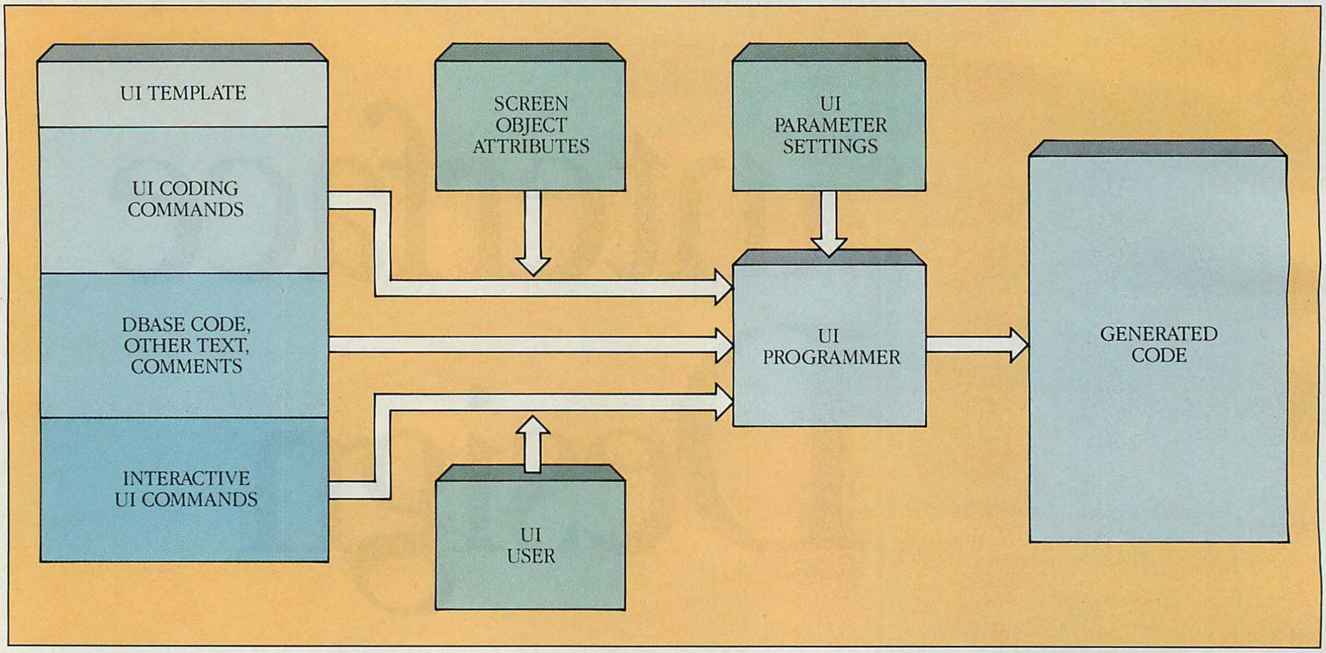
FIGURE 1: ***The UI Code-generation Process***



The UI generation program integrates the text and UI commands from the template with the objects, attributes, and UI parameters selected by the user and any interactive directions input by the user in response to UI query statements in the template.

When UI encounters a label, it generates appropriate code. In contrast to other code generators, the UI template is not stored in code internal to the generator, but in template files. The user can modify the template files directly in order to customize a particular application. The code generation process is shown in figure 1.

To operate UI, the user paints a screen with objects such as boxes, dBASE file fields, memory variables, and text; specifies attributes such as field picture clauses, colors, and menu option definitions; and selects an appropriate template file. UI then generates the output program file.

UI is not an intuitive program, nor is it easy to learn in depth. The operational relationships between the various components of the generation process are powerful and complex, and they must be fully understood in order to exploit their potential. When programming a template file, the programmer must be able to visualize the generated code as well as the impact of changes in screen parameters at generation time. UI calls some of its code-generating commands supermacros in an attempt to relate them to dBASE language macro commands. Programming with these supermacros in conjunction with screen image objects and their attributes is at least one complex level of abstraction above programming with macros in the native dBASE language. The full power of The UI Programmer will be available only to experienced dBASE programmers who make the commitment to thoroughly learn the intricacies of the program. For many application development programmers, the effort will be worthwhile.

PACKAGE AND WARRANTY

WallSoft distributes The UI Programmer on three diskettes with an 800-page manual in a standard-size, three-ring binder with slipcover box. The documentation specifically refers to the interactive tutorial provided on diskette and does not include any additional teaching material. The template files are documented internally within the template code with comments.

The program, which requires 300KB of available memory, will execute from a subdirectory as long as it is included in the DOS path. The DOS shell may be run from UI by pressing the Alt-X key combination.

UI is not copy protected, but it will not execute until it has been installed; installation brands UI.EXE with the user's name and erases the installation program. Registration entitles the owner to unlimited toll-free support, low-cost (often free) upgrades and bug-fix diskettes, and a warranty.

The warranty is one of the best in the business; WallSoft was one of the first companies to warrant software products to work as advertised (to your satisfaction in the first month after purchase) and to agree to fix bugs (found in the first six months) or refund the entire purchase price.

MENU OPTIONS

UI uses function keys F1 through F10 to call a series of pull-down menus that manage the creation of screen images, set parameters, and select template files. The menu names are displayed across the top of the screen in a bar, which may be turned off when the full 25 rows of the screen are needed. Pressing a function key will display the corresponding pull-down menu. For most of the operations, holding the Alt key while pressing the function key will display an abbreviated menu of the first characters of the menu choices instead of the full display of the pull-down menu. See table 1 for a list of the definitions of function keys.

The pull-down menus operate in a manner similar to many programs, such as Ashton-Tate's Framework II, except that the most recent menu operation is not retained in memory. To execute a UI operation such as **box move**, the operator must press the appropriate function key (or Alt plus the function key), and then press the first letter of the desired selection. To reexecute the most recently used UI command, the same keystroke sequence must be performed. When designing a screen in UI, many operations

and operation sequences are used repeatedly, and an "execute-most-recent-menu-selection" key would be useful.

TEMPTING TEMPLATES

The implementation of the template file concept is the most significant feature of The UI Programmer. A template file captures a generalized program algorithm, and the generated program is an instantiation of the algorithm as modified by the generation-time parameters specified by the screen design. *Template files* may be used repeatedly to generate programs that fit the template algorithm, but each generated program is unique to the application specified by the screen. For example, the menu template provided with UI captures a bounce-bar menu algorithm, but a program generated from the template will implement the algorithm for specific menu options, option placement, text, colors, and option actions stipulated by the programmer on the UI screen at generation time.

The significance of templates is that developers can capture common algorithms in template files and use them over and over without modification, tailoring the generated output by specifying elements on the screen. The relationship of transistors to integrated circuits (ICs) is somewhat analagous to the relationship of dBASE language commands to the UI template. The IC becomes the building block of hardware systems, and the templates produce the building blocks of software systems. A library of templates for menus, file views, data validation file look-ups, single-file add/change/delete programs, and so on, permits the developer to design applications in terms of modules, rather than in terms of program definitions and coding techniques. For example, a good menu template will allow the developer to create a menu program in minutes and to modify it just as fast, if necessary. With the mundane task of menu production out of the way, the developer can concentrate on the more important design aspects of the system.

Template files are plain ASCII text files, typically in dBASE program file format, and may be modified by any standard ASCII text editor. The UI Programmer package contains several template files that serve as a beginning set of templates and as examples of template language techniques. Table 2 lists these template file names.

The logic of the generated program is contained in the UI template file, as specified by the template programmer. This is different from many code and application generators where the generated program logic is not available to the developer for modification. Most UI template files are standard dBASE program files where blocks of code of a specific nature are replaced by UI directives to generalize the program into a template.

TABLE 1: ***Function Key Definitions***

KEY	DEFINITION
F1:Help	Calls text file of generalized help, which can be paged through with the up and down arrow keys. This file is an ASCII file, UI.HLP, which also contains text for context-sensitive help available within other menus via F1.
F2:Files	Displays options to load, import, export, and save screen files.
F3:Editing	Provides options to move, copy, and erase areas, join line junctions, and center text; lists key combinations for drawing lines with cursor keys.
F4:Fields	Offers options to select working dBASE .dbf file, display fields on screen, create new fields, modify field definitions and attributes, and order fields for read sequencing.
F5:Boxes	Provides selections to create, move, and edit boxes on screen.
F6:Options	Permits option attributes to be attached to boxes on screen for generating dBASE menu programs. One choice simulates menu execution, showing selected and unselected boxes in turn as cursor or trigger keys are pressed.
F7:Colors	Provides selections to set color for screen background, fields, boxes, and menu options. A pop-up menu of foreground/background colors is used to select desired setting.
F8:Generation	Presents list of template files available for code generation.
F9:Setup	Permits setting of UI parameters, including possible use of Memory Resident Display program and keyboard macro assignments.
F10:Movies	Controls recording and playback of keystroke sequences to create "hands off" scripts within UI. The UI tutorial is based on "movie" scripts created with these options. The primary use of "movies" would seem to be the demonstration of UI techniques in a teaching environment.

The UI Programmer makes extensive use of function keys to display pull-down menus from which the user selects the objects and attributes needed to design a screen or menu. Function key selections appear on the top line of the screen.

VARIATIONS ON A TEMPLATE

UI template commands (labels) come in three varieties: supermacros, predefined characteristic labels (PCLs), and UI directives. Supermacros and PCLs are delimited by {} to distinguish them from other text in the template. UI directives are delimited by <<>> symbols. It is not clear why two different delimiter sets are required.

Supermacros represent pieces of code that UI will place in the generated program when the label is encountered in the template. Supermacro labels come in five categories: **{display . . . }**, **{pop . . . }/{unpop . . . }**, **{get . . . }**, **{say . . . }**, and **{initialize . . . }**. Each category contains specific labels such as **{display text}**, **{pop all boxes}**, **{unpop box}**, **{get all fields}**, **{say all variables}**, or **{initialize all dbfs}**. For example, the **{display text}** label would generate code to display the screen text. The code generated could be a series of dBASE @ . . . SAY statements, or it might be a call to the memory-resident display screen-image manager (MRD.EXE) provided with UI. A **{get all fields}** supermacro label would expand into a series of @ . . . GET statements. All the developer has to do is paint the screen by typing text (and selecting and positioning fields and boxes), press the F8:Generate key, and select a template; UI will place the correct GET code into the generated program. In addition to the individual labels within each category, an "in-box" clause may be applied, where appropriate, to restrict the scope of the label, as in **{get all variables in box}**.

PCLs allow the template program to access specific attributes of objects on the screen at generation time, such as number of boxes, field row, and column. The PCL value is substituted in the generated code where encountered. For example, a template program could include the statement @ **{memvar row}**, **{memvar column}**, SAY

TABLE 2: ***Templates Provided with UI Programmer***

TEMPLATES	DESCRIPTION
APPLICATION:	
AP_BASIC	Basic database application: add/edit/delete with bounce-bar menu.
AP_BDB3	dBASE III version of AP_BASIC.
AP_BROWS	3 Plus add/edit/delete with field-sensitive help.
AP_BWHLP	AP_BASIC plus pop-up help (from box on screen).
DO PROGRAM:	
DO_APPND	Append program: creates and uses memvar dupes of screen fields.
DO_ENTER	Plain entry screen: .PRG with DBF setup and vars initialization.
DO_SCRLW	Scrolling file-lookup window.
DO_SRCH	Record search from screen fields.
MENU:	
MN_BBAR	Bounce-bar (light-bar) menu: horizontal or vertical.
MN_BBPOP	Pop-up bounce-bar menu: menu options in a box.
MN_BBSUB	Submenu template (does not redisplay screen after calls).
MN_YRCH	Your-choice menu (that is, "Your choice: _").
CODE PIECES:	
PC_CLIPH	Clipper "help" pop-ups hooked to all vars on screen.
PC_EZPRC	Basic entry procedures: edit, append, GOTOs, etc.
PC_FMT	FMT file: display text, display vars, input vars.
PC_POPH	Pop-up help program for selected box.
TOOL KIT:	
TL_NUDBF	Generates PRG to create new DBF from all fields on screen.
TL_QEXP	Build query expression from memvar input.
TL_UTIL	Useful template bits.

The nineteen template files provided by UI Programmer for design of basic screens and menus are listed when the F8 function key is depressed. The user may select one of these or may write his own template and add it to the list.

{memvar name}, which would generate a line of code such as @ 10, 20 SAY MLASTNAME. PCLs consist of seven categories: **{number of . . . }**, **{box . . . }**, **{option . . . }**, **{field . . . }**, **{memvar . . . }**, **{dbf . . . }**, and a miscellaneous category. As with supermacros, a number of specific PCLs are available within each PCL category, such as: **{number of dbfs}**, **{box height}**, **{field name}**, **{memvar type}**, or **{dbf alias}**. The miscellaneous category contains PCLs for **{file}**, **{date}**, **{time}**, **{string}**, **{count}**, and **{screen color}**. The **{file}** PCL refers to the name (excluding the extension) of the file being generated, **{date}** and **{time}** refer to the computer system date and time at generation time, and **{screen color}** refers to the color of the screen. The **{string}** and **{count}** PCLs work in conjunction with UI directive labels. The "in-box" clause may be used in several of the PCLs where they are appropriate.

FOLLOWING DIRECTIONS

UI directives commands, delimited by << . . . >>, control the generation process by telling UI what to do rather than actually generating specific code. The four categories of directives are: <<for all . . . >>, <<ask-for . . . >>, <<if . . . >>, and miscellaneous. As with supermacros and PCLs, several specific directives exist within each category, such as <<**ask-for box**>>, <<**for all boxes**>>, <<**if Clipper**>>, and the two miscellaneous directives, <<**title . . .** >> and <<*** . . .** >> (or <<**note . . .** >>).

The <<for all . . . >> directive. This directive provides generation time loops that execute once for each item within the scope of the directive. For example, the <<**for all fields**>> . . . <<**endfor**>> directive iterates once for each field present on the screen. Any text, PCL values, and supermacro expansion-generated code within the loop will be repeated once for each field on the screen. The **{count}** PCL is a numeric counter that increments once for each loop iteration; its value may be incorporated in the output code, but this value cannot be set, tested, or modified within the <<**for all . . .** >> loop at generation time. By the way, the <<**for all . . .** >> loops may not be nested.

The <<ask-for directive>>. This directive allows the template code to request values from the user during the code generation process. The user may be requested to point to a box or memory variable on the screen with the cursor, to enter a string, or to answer yes/no. The value identified by the user may be stored in a UI variable and tested or used subsequently within the template. For example,

<<ask-for box message "Which box is the help box?" =helpbox>>

pauses the generation process, requests the user to indicate a specific box with the cursor, and saves the internal pointer to the specified box in the UI variable helpbox. Subsequent UI commands may make use of the UI variable, as in **{pop helpbox}** or <<**for all memvars in helpbox**>>. Up to 32 UI variables may be set with the <<**ask-for . . .** >> directive. No provision exists to set or manipulate UI variables within the templates other than to request them from the operator and to test or use their values once set.

The <<if . . . >> directive. This directive can examine parameters, as in <<**if Clipper**>> or <<**if MRD**>>; detect the presence of objects on the screen, as in <<**if fields**>>; or test the value of a UI logical variable set by the <<**ask-for y/n**>> directive, as in

<<ask-for y/n = isindex>> <<if isindex>>

Code, text, and UI commands that appear between the directive pair <<**if . . .** >>/<<**endif**>> will be optionally executed or skipped over. An <<**else**>> clause was later incorporated into the <<**if . . .** >>/<<**endif**>> directive after the manual was printed; it is documented in a NEWSTUFF.DOC file. In addition, <<**if . . .** >> directives may not be nested.

The <<title . . . >> directive. This directive is used as a file description by UI. When the user selects the F8:Generate menu, UI reads all template files (with the file extension .TEM) within the designated subdirectory and uses the <<**title . . .** >> directive to prepare a menu of templates for selection. The <<*** . . .** >> and <<**note . . .** >> directives permit comments and documentation to be incorporated in template files. These comments will not pass through to the generated output file.

DESIGNING THE SCREEN

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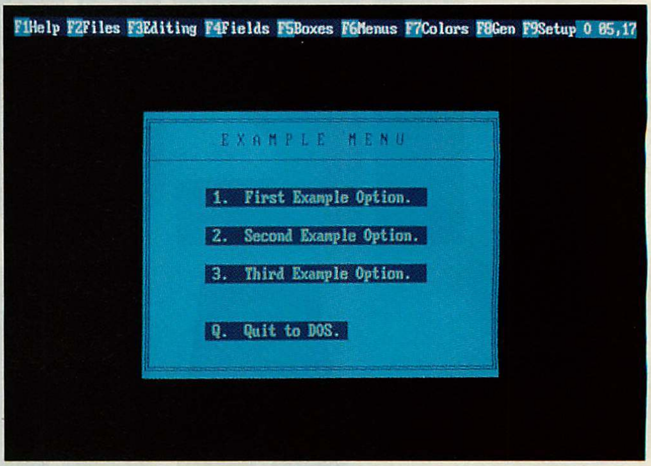
PHOTO 1: *Designing a Data Entry Screen*

The dBASE file, PEOPLE.DBF, is being used to design a screen for data entry. The F2 function key is used to select the file for data entry, F4 to select the fields, F5 to draw boxes, and F3 to edit the screen design.

PHOTO 2: *Sample Menu*



A sample menu is being designed to allow the end user to make a choice by moving a bounce bar. Portions of the template and generated code that will be used to display this menu are illustrated in figure 2.

open dBASE data files and select fields from them, and set colors for various screen objects. Except for text, all elements to be placed on a screen are selected by single keystrokes. For example, to design a screen for data entry, the user types in text prompts; the file, fields, and boxes are obtained by pressing the appropriate function key and making selections from pull-down and pop-up boxes.

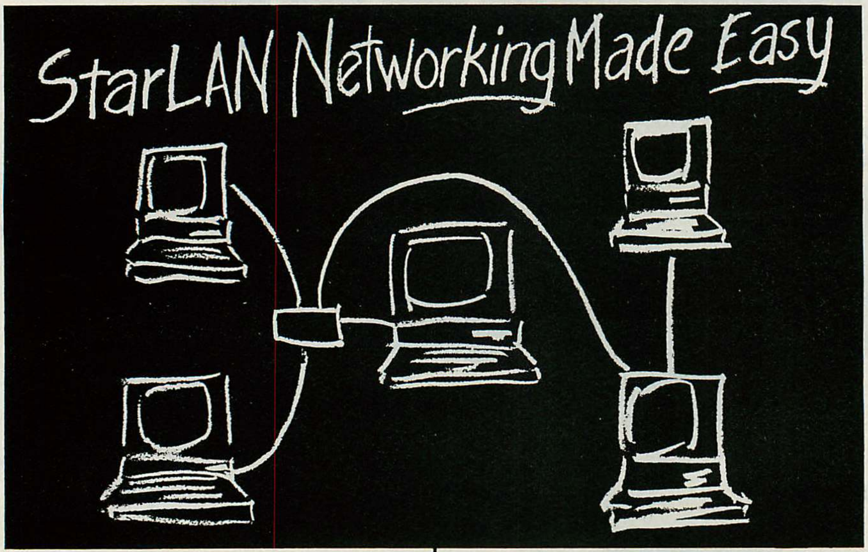
A box bordered by a single line, double line, or no border at all is created by pointing to the desired upper-left corner, selecting the box command from a menu, and moving the cursor to the desired lower-right corner. A box may be moved in three dimensions (horizontal, vertical, and depth) to provide overlapping windows within the generated application. Box size may be adjusted with the cursor using another box edit command, and box colors are set separately for border and contents by interactive selection from a pop-up menu. As many as forty boxes may be defined on a single screen.

Single and double lines may be drawn with the cursor keys, and if instructed, UI will join the horizontal- and vertical-line segments at the corners automatically as the lines are drawn. Line segments also may be joined by placing the cursor at the joint and pressing Ctrl-J; one menu selection will join all line junctions on the screen in a single operation. Any ASCII graphics character also can be selected from a pop-up menu and used as a line-drawing character.

A menu choice opens a a dBASE data file. A single field or a group of fields then can be selected for placement on the screen; up to 128 fields from any number of data files may be used. Data fields may be moved on the screen as individual objects, or as a part of a relocated area using the **move area** editing command (see photo 1).

Text may be placed anywhere on the screen, and the cursor will wrap on carriage return to the left side of a defined box for ease of text entry. Text may overwrite a box border without destroying the box definition, but text may not overlap a field definition area.

Screens are stored in internal UI format-screen-image files with a .WW extension, with one screen stored per file. Screens may be exported to ASCII



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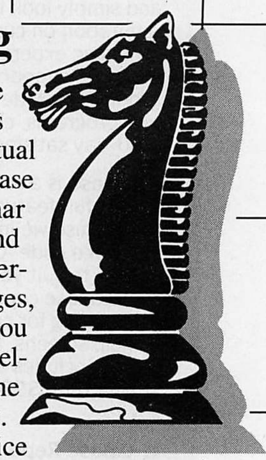

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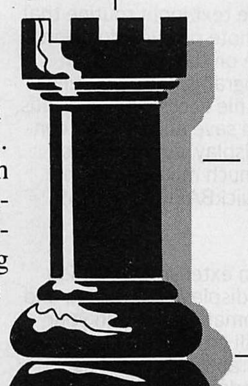

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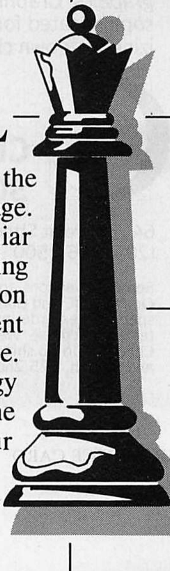

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format for documentation, and ASCII screen images may be imported to the UI screen. UI also will read a dBASE program file and build a screen from the @ . . . SAY and box-drawing commands. UI does not permit screens to extend beyond the single-screen size of 80 columns by 25 rows.

The screen editor can be rather awkward to use, although parts of its operation can be smoothed out with the UI macro key assignment utility, which allows the user to tailor the keyboard for individual use.

As with any screen-design tool, the cursor often must be moved from one point on the screen to a distant point on the screen. UI provides definitions for keys such as Tab, Home, and End for distance movements, but these definitions do not work when highlighting an area to be moved with the **move area** command. To increase performance, a keyboard speed enhancement program can be used effectively with The UI Programmer. In addition, a mouse interface can be created to speed up screen-design operations.

Another awkward operation is expanding a box to add contents. Boxes can only be expanded from the lower-right corner; contents must then be highlighted with the **move area** command and moved to the desired location. An option for sizing boxes from the upper-left corner would be useful.

One common operation is to copy a box repeatedly when creating menu screens. The ability to reexecute the box copy command with a single keystroke also would be helpful.

SCREEN IMAGE ATTRIBUTES

UI considers the text, fields, and boxes on the screen to be objects to which attributes (UI documentation refers to them as characteristics) are attached. These attributes are examined by commands in the template file during the code-generation process and, therefore, influence the generated program code. Some of the attributes are inherent, such as the object's location on the screen (row and column), whereas other attributes may be assigned or modified by the UI user.

Text is considered to be either in a box or on the full screen, and may have a foreground/background color attribute assigned. Box border lines are also considered text, but may have a color attribute assignment different from the text within the box. Individual pieces of text cannot be separately colored unless they are placed within individual boxes, a somewhat awkward approach to multicolored screens.

A field object has several attributes that are set or modified using a pop-up data screen. The field name may be up to 20 characters in length, or the field name may be a dBASE language expression, such as **str(recno( ),4,0)**, as long as the programmer is careful not to generate code that would attempt to accept data into the field. The type, length, and number of decimals conform to the dBASE file field attributes; no special handling is provided for memo field types. The field may be designated as a memory variable or a database field. For database field variables, the database file name may be assigned, along with the alias used when the file is opened in dBASE. The variable may be designated as display only, to coordinate with template commands that generate code to display or accept data to variables. A dBASE picture clause may be attached (up to 68 characters long), as well as a validation expression for Clipper programs. Another attribute command available from the UI Fields menu allows the pro-

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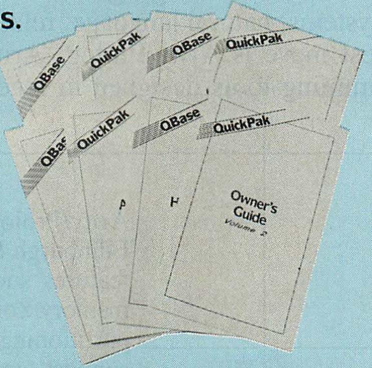

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grammer to specify the sequence in which the generated program presents fields to the end-user for data input.

Boxes have several attributes. The box location and size attributes include upper-left-corner row and column, height in number of rows, and width in number of columns. Although boxes may appear on top of or below other boxes on the screen, this depth attribute is not available for manipulation by template directives at generation time. The box outline color and contents color are completely separate attributes. Menu option attributes may be attached to any box for the purpose of interactive menu-code generation. The menu attributes consist of a trigger character and a maximum of three lines of text or dBASE code that can be assigned to the option action attribute. Typically, menu selection options are painted on the screen in no-border boxes, and a menu option is defined for each desired menu selection; the option-action code is usually a procedure call that is to be executed when the menu choice is selected. Additionally, selected and unselected color attributes may be assigned for use in creating bounce-bar menu programs.

CREATING MENUS AND SCREENS

One common use of UI is to generate menu programs that display bounce-bar menus for the user; the UI template file MN_BBAR.TEM will generate such menus. The given template works well, but generated menu programs cannot be nested (menus calling menus) unless four variables (**newchoice**, **numopts**, **oldchoice**, and **optkeys**) are made private to avoid conflict with the same-named variables in higher level programs. Photo 2 shows a sample menu; figure 2 shows portions of the MN_BBAR template file along with the corresponding generated code for a simple menu application, illustrating some of the template command usage.

Another common use of The UI Programmer is as a screen generator. The high-level supermacros may be used in templates, or individual attributes may be accessed through PCLs. For example, the **{get all fields in box}** command would produce a line of code such as the following for each field in the designated box for which the display only attribute was not set:

```
@ 10,20 GET STK→ITEMNAME PICTURE
    "!!!!!!!!!!" VALID okitem()
```

On the other hand, the template programmer might generate the above code through the use of alternate tem-

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FIGURE 2: *Template Versus Generated Code*

```
EXAMPLE TEMPLATE
   ***
   *** {file}.PRG : Main menu.
   *** Generated {date}
   ***

   * menu initialization
   optkeys = "<<for all options>>
              {option trigger}<<endfor>>"
   numopts = {number of options}
   * display the menu screen
   {display text}

        * highlight new option
         do case
   <<for all options>>
          case newchoice ={count}
            {display option selected}
   <<endfor>>
         endcase

      * perform selected option
      do case
   <<for all options>>
       case newchoice ={count}
         {option action}
   <<endfor>>
      endcase
```

```
GENERATED CODE
   ***
   *** MENUFIG.PRG : Main menu.
   *** Generated July 26, 1987
   ***

   * menu initialization
   optkeys = "123Q"
   numopts = 4

   * display the menu screen
   SET COLOR TO W/N
   CLEAR
   SET COLOR TO B/BG
   @ 05,15,18,59 BOX "┌─┐║┘─└║ "
   @ 07,15 SAY "╟"
   @ 07,59 SAY "╢"
   @ 06,25 SAY "E X A M P L E   M E N U"
   @ 07,16 SAY "───────────────────────────────────────────"
   @ 09,23 SAY " 1.  First Example Option.  "
   @ 11,23 SAY " 2.  Second Example Option. "
   @ 13,23 SAY " 3.  Third Example Option.  "
   @ 16,23 SAY " Q.  Quit to DOS. "

      * highlight new option
      do case
        case newchoice =1
          SET COLOR TO +G/B
          @ 09,23 SAY " 1.  First Example Option.  "

        case newchoice =2
          SET COLOR TO +G/B
          @ 11,23 SAY " 2.  Second Example Option. "

        case newchoice =3
          SET COLOR TO +G/B
          @ 13,23 SAY " 3.  Third Example Option.  "

        case newchoice =4
          SET COLOR TO +G/B
          @ 16,23 SAY " Q.  Quit to DOS. "
      endcase

      * perform selected option
     do case
       case newchoice =1
         do OPTION1
       case newchoice =2
         do OPTION2
       case newchoice =3
         do OPTION3
       case newchoice =4
         QUIT
       endcase
```

The code on the left shows portions of the template, MN_BBAR.TEM, used to generate a simple menu with bounce-bar selection. The code on the right shows the corresponding dBASE program code generated by UI from the template when the user designed the specific menu shown in photo 2. The template can be modified easily to produce other menus.

plate commands to access these attributes individually, such as:

```
<<for all getfields in box >>
@ {field row},{field col}
GET {field dbf} → {field name}
PICTURE {field picture}
VALID {field valid} <<endfor >>
```

The current level of template language power makes UI suitable for generation of menus and screens as well as application building blocks and simple applications. However, more power and flexibility in the template language will be required before templates for complex application systems can be developed. In spite of this limitation, many application building blocks can be prepared using templates developed for the current UI program. These modules include support file maintenance modules such as add, change, delete and list. Many other simple but tedious programming tasks that require repetitive operations also can be automated and the resulting modules are then integrated into application systems.

MANAGING SCREEN IMAGES

Pop-up boxes for help, reference information, and data entry are an important part of professional applications, whether coded in dBASE or in some other language. The native dBASE III and dBASE III PLUS products have no functions to save and restore the screen during program execution, so many code generators have addressed this deficiency by providing memory-resident, screen-image manager programs callable from dBASE programs; for example, the Clipper compiler allows a

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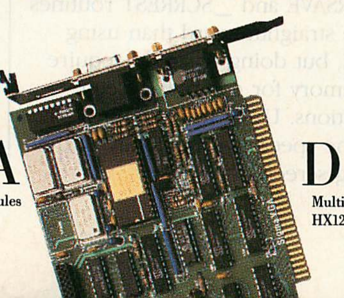

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program to save the current screen to a memory variable and restore it at a later time. WallSoft provides the MRD.EXE program for this purpose.

MRD.EXE is a memory-resident display program that manages screen images stored in screen image files (.SIF). This program is loaded before the dBASE language interpreter or compiled dBASE program. Interpreters using DOS interrupt 10H, such as dBASE III, can pass screen-management commands to the MRD by printing them to the screen preceded by two **chr(255)** characters. For interpreters with a LOAD/CALL facility, the program MRDCMD.BIN can be used to communicate with the resident MRD.EXE. MRDCMD.OBJ can be linked with a compiled dBASE program to provide access to MRD.EXE as well. In addition, source code (MRDCMD.ASM) is provided, and an executable version (MRDCMD.COM) can be used to test and manage .SIF screen files from the DOS prompt. WallSoft does not require a royalty or license fee to incorporate the MRD programs into application systems for distribution.

Screen image files can contain one or more screen images, and several .SIF files may be loaded simultaneously. UI will generate .SIF files for screen management if the MRD parameter is specified in the F9:Setup menu, and will produce calls to MRD.EXE in the generated code, where appropriate. The .SIF image file may contain several image segments, such as two for each menu option—one in its selected (that is, highlighted) state, and one in its unselected (that is, lowlighted) state. Menus then can be presented to the user without any special **@ . . . SAY** code being necessary for option display. Additionally, images that are stored in .SIF files may be dynamically located on the screen at execution time so that multiple pop-up box images do not have to be saved.

The usual risk of conflicts between memory-resident programs exists when MRD.EXE is used, although no such conflicts have been noticed. When Clipper is the target dBASE dialect, calls to the _SCRSAVE and _SCRREST routines are more straightforward than using MRD.EXE, but doing so could require more memory for complex screen manipulations. Using the MRD increases the speed and flexibility of the displaying screens.

GENERATING CODE

The UI generation process brings together input from a variety of sources to create an output file of generated code. The UI Programmer integrates raw source code and text from the selected template file, UI parameter settings, attributes of objects on the screen, code and text generated from UI language statements in the template, and interactive directions from the user's response to UI query statements in the template. Figure 1 illustrates the component relationships of this process. To initiate code generation, the user creates a screen image or loads one from a previously saved image file, selects the appropriate template file, and confirms or enters the output file name (which defaults to the screen file name with a .PRG extension).

Some items in the template pass through to the generated output file unchanged. Any characters on any line in the template that are not within the area bounded by UI-specific delimiter pairs ({ . . . } and << . . . >>) are transferred exactly as is to the output file. dBASE statements, including source code and comments, are copied directly to the output file, as are any text lines whether legal in dBASE or not. In fact, dBASE source code files and any other text files are legal templates that will cause the generation of exact copies of themselves in the UI output file.

UI parameters set from the F9:Setup menu also affect the way UI generates code. Two parameter flags can be set to values that affect the output of some UI commands in the template files. These parameter settings may also be tested by the **<<if . . . >>** command for use in conditional code generation techniques within templates. One parameter, **dBASE flavor**, may be set to one of the following values: dBASE III, dBASE III PLUS/FoxBASE+, or Clipper compiler. (The manual states that the second setting includes Quicksilver along with dBASE III PLUS/FoxBASE+.) The other parameter, **display text, may be set to @ . . . SAY** or **calls to MRD.EXE**. In addition, a generated code directory parameter may be set to a default directory path for the output generated code files; this setting may be overridden at generation time. UI saves these parameter settings by modifying UI.EXE; they take effect at the time of setting and remain in effect through subsequent executions of UI.EXE until the settings are modified again or a different copy of UI.EXE is used. (The disadvantages of this method outweigh the advantages.

For example, a CONFIG.UI or other parameter file that can be edited would provide more flexibility and less chance for error when UI is used for more than one project.)

These parameter settings have a limited effect on UI-directed code generation; the main consequence is in the selection of the dBASE dialect flavor of box-drawing commands when generated code draws boxes on the screen. However, substantial impact in the generated code may be created by the template programmer through conditional code generation based on the value of these settings as determined with the UI <<if . . . > > directive; such templates can automatically tailor the output code to the target system defined by the UI parameter setting. In addition, the Clipper setting will also provide automatic invocation of the Clipper VALID clause when generating code for input variables defined on the screen for which a VALID attribute has been assigned. The Clipper setting may also affect the way the screen is restored when a box is unpopped, depending on the setting of the Display text parameter.

The Display text parameter affects the way code is generated to display text data on the screen. In the @ . . . **SAY** setting, text is presented on the screen using a combination of the dBASE @ . . . **SAY** command and the box-drawing commands of the selected language dialect. The generated code appears similar to that produced by most dBASE programmers, except that UI breaks the text to be presented into sections to optimize display speed. The MRD setting causes UI to generate code that will use the MRD system to present data on the screen from predefined screen-image files. The parameter combination of Clipper and @ . . . **SAY** will generate screen-display code that makes use of the Clipper _SCRSAVE and _SCRREST subroutines that help to manage screen images when boxes are popped and unpopped.

ROOM FOR IMPROVEMENT

The UI Programmer is a useful tool that can help automate programming. It is both an instrument for the experienced dBASE programmer to create code-generation tools for application development, and a vehicle for less experienced programmers to use these tools. The skilled dBASE programmer who learns to develop general-purpose, code-generation templates and integrates them into his system development style can substantially increase productivity. The less experienced programmer who uses well-designed templates developed by others can significantly decrease coding and debugging time. In a group of programmers developing applications to support an organization, template libraries can be used to help standardize the look and feel of programs produced by the group, and can reduce the time required to indoctrinate new programmers into the group.

The UI template language concept is quite powerful and may be the beginning of a fourth-generation language for dBASE developers. In the first release of UI, however, the language is primarily limited by the lack of ability to set, test, and manipulate UI template variables. Nested <<if . . . > > and <<for . . . > > directives would also be useful. Language extensions to permit templates to call other templates, to access multiple screens at generation time, to allow user-defined supermacros, and to generate multiple output files in a single process would allow the creation of templates for the generation of full applications. Further development of the template language would also make it more of a language in its own right, instead of seeming at times to be a cryptic extension of dBASE. The template language could be made language-independent with only minor modifications being necessary; user-interface programming is certainly not a chore exclusive to dBASE.

Correspondence included with the product package indicates that the development of UI was evolutionary in nature; feedback from prerelease users and beta testers was used to shape the definition of the program. This approach contrasts with the traditional sequence of development—identifying requirements, developing specifications, designing the program, and finally producing the product. The evolutionary approach used to develop the UI programmer is both good and bad. The UI template language suffers from a lack of elegance and completeness, but the end result is still a useful and powerful tool. Hopefully, the next release will incorporate improvements in the template language (see the accompanying sidebar for the anticipated additional commands and features).

In its first release, The UI Programmer is neither a true fourth-generation language nor an application gen-

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erator. One of its most significant features is the ability to use the attributes of objects on the screen to influence the code produced by the template file commands during the generation process. This feature provides a substantial degree of access to screen object attributes from within the template. The UI template language is both powerful and primitive; after expending the effort to learn the language in depth, the user appreciates the results but wishes for more powerful language commands and richer syntax. Extensions to the template language could easily allow the creation of true application-generating template libraries, and also permit the development of language-independent code generator tools.

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Dave Browning is vice president and co-owner of WBS and Associates, Inc., a microcomputer and custom database consulting firm. He is also director of vendor relations and chairman of the database special interest group for the Capital PC User Group.

ANTICIPATED UPDATE

At the time this article was being prepared, UI Programmer release level was 1a. A new version with substantial enhancements is expected about the time that this article appears in print. WallSoft Systems provided the following general information about the changes and improvements planned for the next release.

The primary intent of the next upgrade will be to improve the template language by incorporating additional commands and features, such as the following:

- Callable template files (template files that can be called from other template files)
- Generation of multiple output files, user-defined supermacros, and the **while**, **for**, **case**, **if**, and **iif** statements
- Removal of dBASE specific syntax from generated code (language independence)
- More power to drive UI.EXE from template files at generation time
- Ability of directives to load screen image files during generation for multiple screen programs
- More complete control of UI template variables
- Ability to access the screen text by its location
- Character-by-character text color
- Additional object characteristics, such as names for boxes
- Ability of template functions to manipulate attribute characteristics
- Larger limits on the number of fields and boxes
- CONFIG.UI file for UI parameters.

All of these improvements will be welcome, and are a result of feedback from UI users. The attention to user response underscores the WallSoft concept of developing the program in an evolutionary manner by incorporating features requested by UI Programmer users.

In addition, WallSoft Systems will continue its six-month warranty. WallSoft also maintains a registry of UI Programmers who custom design templates for specific purposes; this service makes UI available to individuals who do not want to do their own template programming.

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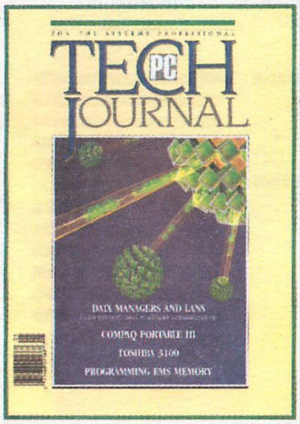

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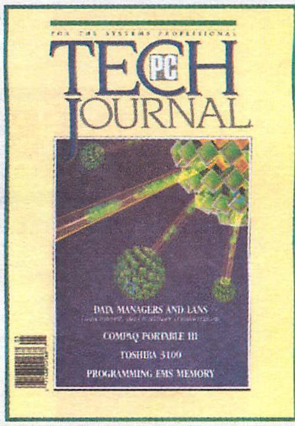

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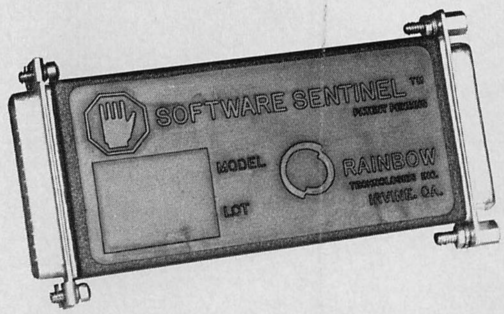

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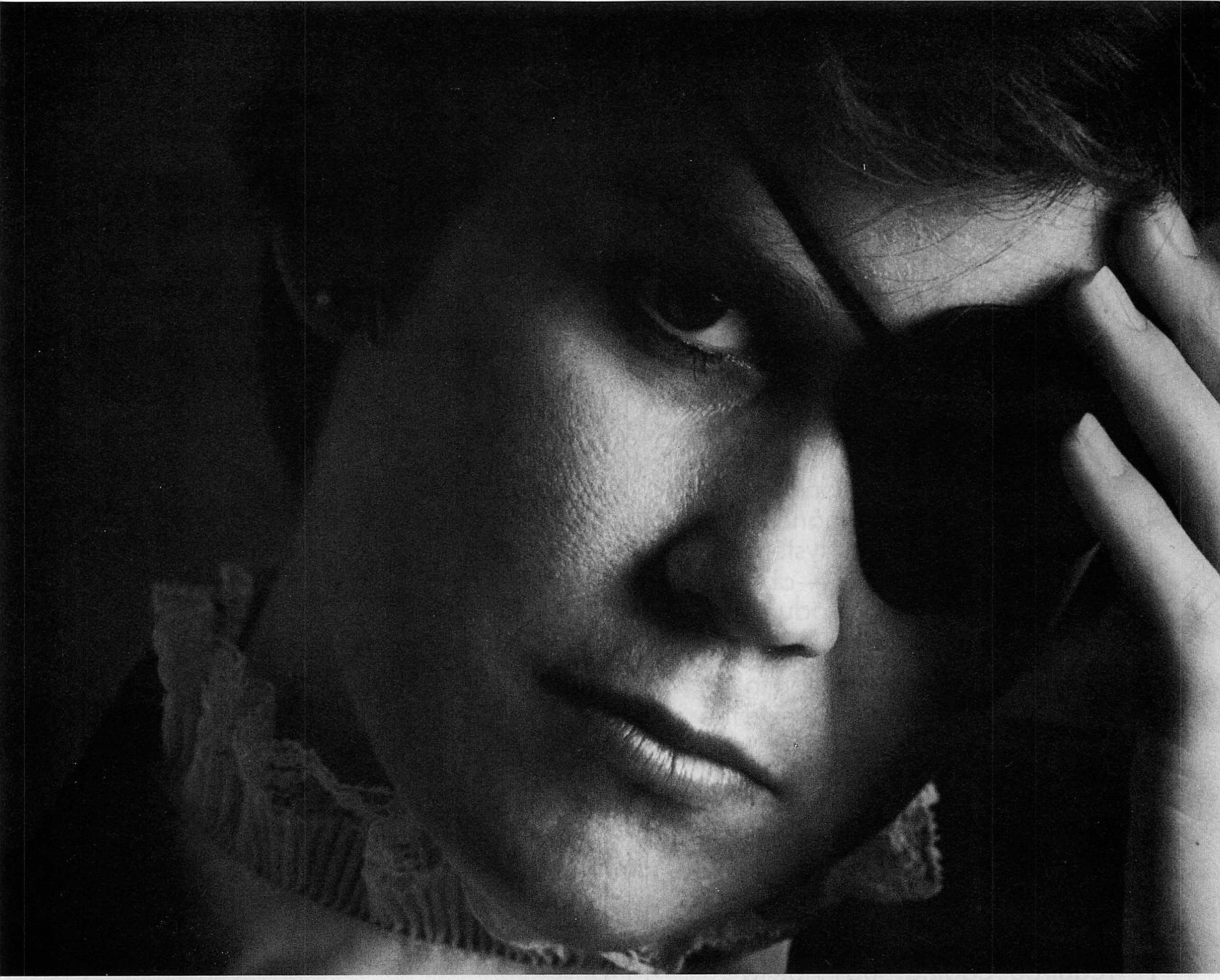

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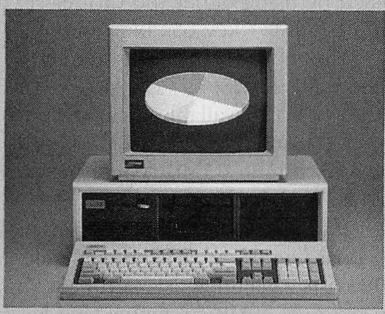

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Compaq Computer Corporation has updated and enhanced its time-tested Deskpro Series. The Deskpro 386, following *PC Tech Journal*'s review of the unit earlier this year (see "The New Standard," Steven Armbrust and Ted Forgeron, March 1987, p. 48), has been enhanced with a new 16-MHz 80387 math coprocessor for faster floating-point operations and a disk-caching program for better memory use in disk-intensive applications (see "The Cache Factor," Maxine Fontana, August 1987, p. 168). The Deskpro 286, reviewed more than a year ago by *PC Tech Journal* (see "Compaq Deskpro 286," Steven Armbrust and Ted Forgeron, August 1986, p. 80), has been updated with a speedy 8/12-MHz 80286 processor, an enhanced keyboard, and the Compaq disk-caching program, CACHE.

With these enhancements, the Compaq Deskpro units, which are already competitors of the IBM Personal System/2 (PS/2) line, become even stronger PS/2 rivals. The Deskpro 386 remains a viable alternative to the PS/2 Model 80 while the Deskpro 286 challenges the PS/2 Models 50 and 60.

DESKPRO 386

In September 1986, Compaq leapt ahead of the personal computer industry with the release of the Deskpro 386 personal computer. This computer, equipped with a 16-MHz Intel 80386 microprocessor, 32-bit memory, and a speedy hard-disk drive, provided IBM PC/AT compatibility at twice the performance. In its initial review, *PC Tech Journal* noted one primary deficiency: the lack of an Intel 80387 math coprocessor. In May 1987, however, Compaq corrected this deficiency.

Since May 4, all Deskpro 386 personal computers being shipped contain sockets for both the 80287 and the 80387 math coprocessors. Compaq users can choose which coprocessor to use, depending on their specific applications. Owners who purchased the original Deskpro 386 can update their machines by exchanging the original system board for one with an installed 80387 chip. The cost of the exchange, available through authorized Compaq dealers, is $999 until December 31, 1987. This is only slightly more than the retail price of the 80387 chip alone.

So why throw away the 80287 chip that your company just paid $500 for and pay another $1,000? The answer is speed. For math-intensive processing, such as CAD applications or scientific programming, the addition of the 80387 allows Deskpro 386 to reach its full potential. The Intel 80387 is a full-fledged 16-MHz, 32-bit chip. By taking in data 32 bits at a time from the Compaq bus and processing it at 16 MHz, floating-point operations are significantly accelerated. Using the ATFLOAT test, developed by *PC Tech Journal* (see "Out From The Shadow of IBM," Steven Armbrust, Ted Forgeron, and Paul Pierce, August 1986, p. 53) to measure the speed of floating-point-intensive operations, the 80387 math coprocessor performs 6.3 times faster than the standard AT, whereas the 80287 coprocessor is only 1.7 times faster.

The 80387 math coprocessor offers all of the operations of its predecessors, plus several enhancements. Many instructions, such as sine and cosine, have been optimized to reduce the number of clock cycles required, providing even more performance acceleration. The chip can perform sine and cosine operations simultaneously on the same operand. This feature is particularly useful for processing graphic images. A wider range of operands is available for the tan, arctan, and natural log functions. The conformance of math operations to the IEEE 754 floating-point standard has been improved. Performance figures in table 1 show that improved floating-point operation constitutes the major difference between the original Deskpro 386 and the new version that is equipped with the 80387 math coprocessor.

Yet another change is the addition of Compaq's CACHE, which is flexible in that it can be used in base, extended, or expanded memory. Use of CACHE improves disk access speed substantially. Using *PC Tech Journal*'s ATDISK test, which measures writing and reading of ten 20KB files, CACHE reduces writing and reading time from 9.0 to 6.4 seconds. The new version of

Compaq 386 is still equipped with the memory-management programs, VDISK (a RAM-disk program), and CEMM (the Compaq Expanded Memory Manager), to allow ordinary applications to use the memory that is not available through normal DOS operations.

Other than adding the 80387 math coprocessor socket and CACHE, Compaq 386 has not changed significantly. The BIOS date is only two weeks later than the previous version—from 8/19/86 to 9/4/86. The Compaq memory board still provides quick memory access. Two Torx screwdrivers are still required to work under the hood, a T-15 to remove the cover and a T-10 to add or remove expansion boards. Three DIP switches on the system board indicate, respectively, the coprocessor's presence, whether it is a 80387 or a 80287, and its clock speed (4 or 8 MHz) if it is a 80287.

All hardware tested in the original review (Hayes' Smartmodem, Intel's AboveBoard/AT, Microsoft's Mouse, Cheetah's memory board) works as well in the new version, as does all software tested (Microsoft's Windows and Word; Borland's SuperKey, SideKick, and Turbo Lightning; Living Videotext's Ready; Hayes' Smartcom II; Fifth Generation System's Fastback; and Intel's QUIKMEM). The IBM Advanced Diagnostics continued to recognize only the first 640KB of Deskpro 386's 1MB of memory. The Advanced Diagnostics' coprocessor test failed because of the presence of a math coprocessor chip unfamiliar to IBM.

—DAVID CLAIBORNE

DESKPRO 286

Compaq's latest version of Deskpro 286 (Model 40) is a solid, well-built unit containing several improvements over the previous version reviewed by *PC Tech Journal* over one year ago. One feature that lends the new 286 its competitive edge is an 8/12-MHz processor operating in conjunction with its 8-MHz IBM PC/AT compatible bus, which replaces the earlier 6/8-MHz processor. At high speed, the 12-MHz processor performs at about 1.5 times the speed of the standard 8-MHz AT and, at 8-MHz clock speed, closely matches standard AT performance.

There are two ways to switch processor speeds, either by using the Ctrl-Alt-\ keys simultaneously, where one beep indicates switching to 8-MHz speed and two beeps switching to 12-MHz speed, or by issuing the **MODE SPEED** command:

```
[d:][path]MODE SPE[=][n]
```

Setting **[n]** to **hig[h]** switches the speed to 12 MHz, setting it to **fas[t]** forces it to 8 MHz, and setting it equal to **o** (for **aut[o]**) sets the clock speed to 12 MHz but automatically reduces this to 8 MHz during diskette access. The command:

```
MODE = aut[o]
```

also causes the CPU to operate at 12 MHz, slowing to 8 MHz during diskette access. The 80287 math coprocessor always runs at 8 MHz regardless of the 80286 processor speed.

The new keyboard, which is the same as the one provided with the Deskpro 386, is the Compaq equivalent of the IBM-enhanced keyboard, having 101 keys, including two alternate and two control keys, with 12 function keys arranged along the top of the keyboard and a separate cursor pad between the numeric keypad and the alphabetic keys. Unlike IBM's keyboard, it has sharp edges, is lighter, is less thick, and has a less curved surface. Compaq's keyboard attaches to the left front end of the computer and is equipped with a cable that is long (about 4 feet, coiled) but does not cause storage problems. The keyboard connector's plastic protective sleeve is a nuisance. Its length and stiffness make it impossible to put the keyboard up against the unit, as is often required in limited-space work areas. None of the keys stuck or showed any other problems. Key clicks are generated by the computer, and their volume can be adjusted by using either the Ctrl-Alt- + or the Ctrl-Alt- − key combination.

The most notable software supplied with the 286 is Compaq's CACHE. Other options available include up to three 2MB memory expansion boards for a maximum 8.1MB system memory and a 70MB hard disk.

In addition to its faster clock, new keyboard, and CACHE, the new Model 40 boasts a half-height 40MB hard disk, an optional 40MB streaming-tape hard-disk backup unit, an enhanced keyboard, and 640KB memory. Other features are a realtime clock, a 5.25-inch 1.2MB diskette drive, an 8-MHz 80287 socket, and built-in parallel and serial ports. There are five 8/16-bit and two 8-bit expansion slots.

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There were six available expansion slots on the unit tested, five 8/16-bit slots and one half-length 8-bit slot. The leftmost 8/16-bit slot is covered by an easily removable brace; all seven full-length slots end at the molded-in guides on the speaker mount, restricting the choice of expansion boards. All memory consists of socketed 256KB chips in banks of nine, with 512KB standard, 1152KB on the tested unit, and room for a total of eight banks for 2MB. The 7.2-V lithium battery is mounted on the rear panel adjacent to the expansion slots and is attached by a Velcro strip so strong that the mounting glue would separate before the strips would part. Serial and parallel ports are mounted on the 9-inch, 16-bit drive controller card.

The test unit came equipped with a Compaq color monitor, a Compaq Enhanced Color Graphics board, and an 8-MHz 80287 coprocessor already installed, along with extra system board memory to bring the unit up to 1152KB, and the front-panel 40MB Compaq streaming-tape hard-disk backup unit (MS-DOS 3.2 and BASIC were not included). With a half-height 40MB hard disk, the tape unit, and a half-height diskette drive in place, the Model 40 has one half-height opening left. The Compaq board is keyboard-switchable between text and graphics modes (Ctrl-Alt- < or Ctrl-Alt- > key sequences), offering 16 colors from a palette of 64, screen memory of 256KB, 2 RCA jacks, light-pen interface, enhanced RGB, and 640-by-350 pixel resolution compatible with the Enhanced Graphics Adapter (EGA). The optional 40MB tape backup unit uses the DC 2000 tape cartridge that took 37 minutes to format. Backup of 7.5MB of data took 7 hours and 43 minutes. Multiple backups can be done on a single tape.

Tests of the new Deskpro 286 Model 40 revealed no compatibility problems, at either 8 or 12 MHz, with most of the standard programs and hardware used in *PC Tech Journal*'s evaluations. Add-on products tested included Intel's AboveBoard/AT with 4MB of memory, a Microsoft bus mouse, a Hayes' Smartmodem 1200B, an IBM EGA and display, and Cheetah's memory board. Software tested included Microsoft's Windows and Word; Borland's memory-resident programs, SideKick, SuperKey, and Turbo Lightning; Living Video Text's expanded memory program, Ready; Hayes' Smartcom II; Fifth Generation System's Fastback, and Intel's QUIKMEM.

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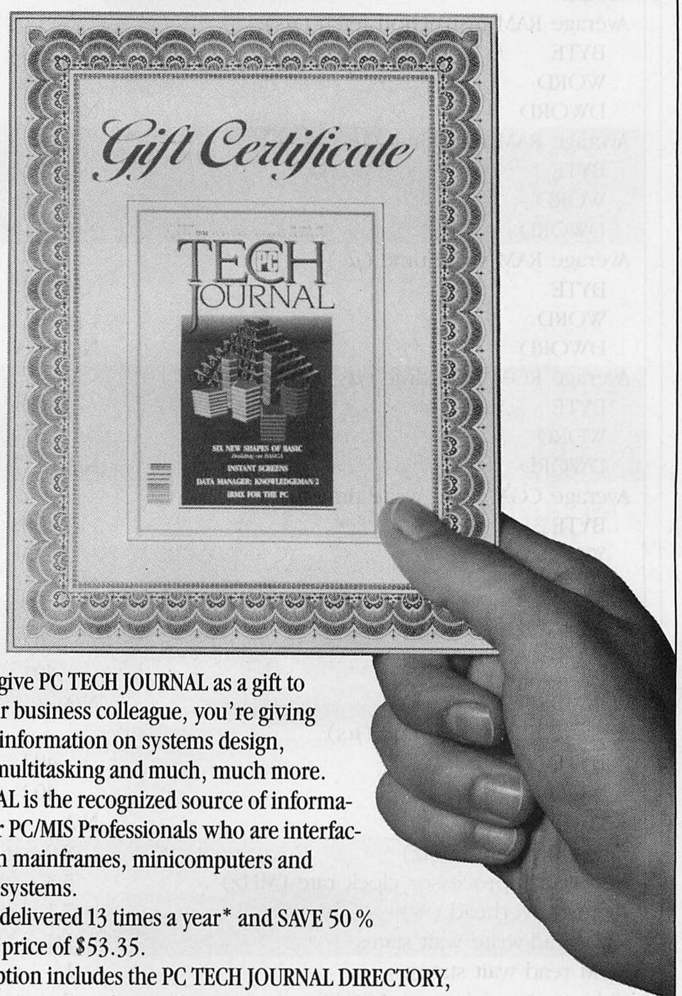

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TABLE 1: *Compatibility and Performance Tests*

	8-MHz AT, 30MB DISK[a]	DESKPRO 386, 80387 INSTALLED	DESKPRO 286 40 MB DISK[b]
ATBIOS			
ROM BIOS date	11/15/85	09/04/86	05/15/87
ATPERF			
Average RAM instruction fetch (μs)			
BYTE	.250	.19 (130)[c]	0.17 (150)
WORD	.403	.14 (280)	0.27 (150)
DWORD	N/A	.23	
Average RAM read time (μs)[d]			
BYTE	.401	.13/.26 (298/154)	0.28 (144)
WORD	.401	.13/.26 (298/154)	0.28 (144)
DWORD	N/A	.14/.26	N/A
Average RAM write time (μs)[d]			
BYTE	.401	.13/.26 (307/154)	0.26 (155)
WORD	.401	.13/.26 (307/154)	0.26 (155)
DWORD	N/A	.13/.26	N/A
Average ROM read time (μs)			
BYTE	.401	Same as RAM read	0.28 (144)
WORD	.401	Same as RAM read	0.28 (144)
DWORD	N/A	Same as RAM read	
Average CGA video write time (μs)			
BYTE	1.208	1.21 (100)	1.21 (100)
WORD	2.415	2.42 (100)	2.41 (100)
DWORD	N/A	4.83	N/A
Average EMM read time (μs)[e]			
BYTE	.402	.13 (301)	.40 (99)
WORD	.402	.13 (301)	.40 (99)
DWORD	N/A	.14	
Average EEM write time (μs)			
BYTE	.402	.13 (306)	.40 (99)
WORD	.402	.13 (306)	.40 (99)
DWORD	N/A	.13	
CPU clock rate (MHz)	8.0	16.0 (200)	11.8 (147)
Numeric coprocessor clock rate (MHz)	5.3	16.0 (302)	7.9 (148)
Refresh overhead (%)	7.1	15	5.7
RAM read/write wait states	1/1	0/0	1/1
ROM read wait states	1	Same as RAM read	1
Video write wait states (CGA)	8	17	12
EMM read/write wait states	1/1	0/0	2/2
ATFLOAT			
Performance (%) relative to AT	100	630	140
ATDISK[f]			
Sectors per track	17	17	17
Heads	5	5	5
Cylinders	731	978	978
Total space (million bytes)	31.81	42.56	42.56
Track-track seek time (ms)	6.0	4.2	4.0
Average seek time (ms)	37.1	26.8	27
Effective transfer rate (KB/sec)	170.1	255.0	255.0
DOS file I/O (sec)[g] (with/without cache)	7.3	5.5/7.4	5.9/7.3
Interleave	3	2	2

[a] *IBM AT figures are average results from several machines; results from Compaq Deskpro 386 are only from the review sample model.*
[b] *In automode at 12-MHz*
[c] *Figures in parentheses represent the relative performance expressed as a percentage compared to* PC Tech Journal's *baseline machine, the 8-MHz, 30MB AT.*
[d] *For the Deskpro 386, first number is for memory access within the same 2KB page; the second is not within the same 2KB page.*
[e] *EMM measurements were taken using the Deskpro 386's CEMM.*
[f] *Disk times were not affected by whether the CPU operated in high-speed mode (12-MHz) or auto MODE that only drops to 8-MHz for diskette I/O.*
[g] *Deskpro 286 and 386 tested with/without disk-caching program.*

Improved floating-point operation is the major difference between Deskpro 386 and the version equipped with the 80387 socket. The Deskpro 286's 12-MHz processor improves performance overall. CACHE improves disk access speed.

Fastback reported a problem with direct memory access, a common problem with non-IBM machines, but it appeared to work correctly at 8 MHz. AboveBoard, using the manual instructions, worked perfectly in both the 8- and the 12-MHz modes.

All compatibility tests were performed with and without the Compaq-included disk cache. As a matter of fact, CACHE significantly improved the apparent disk transfer rate and did not cause any problems.

In almost all cases, the Deskpro 286 operating at 12 MHz outperformed the AT and the Deskpro 286 operating at 8 MHz (see results in table 1).

Although Cheetah's high-speed memory board operated in the new Deskpro, *PC Tech Journal* benchmark tests showed no performance increase over the system board memory at 12 MHz, with both types of memory indicating one wait state.

Using the 256KB CACHE with the standard system at 12 MHz, the Deskpro 286 completed the ATDISK writing and reading of ten 20KB files in 5.9 seconds versus a speed of 17.3 seconds without the CACHE.

Track-to-track time at 4.0 milliseconds and average seek time at 27.0 milliseconds remained the same for all configurations and speeds.

A T-15 TORX or flat-blade screwdriver is still required to remove Deskpro 286's cover. Insertion of the Cheetah memory board and the Hayes 1200B internal modem is simple, as the unit's cover plates need only to be unscrewed and the cards slid in. The 8-MHz 80287 socket is easily accessible next to the power supply. Access to the socketed memory chips is simple: none of them are covered by the drive bays, and only the first bank (0-256KB) are under the speaker/card end mount. When all full-length cards are out of the unit, the speaker can be removed easily without tools.

The tape backup unit includes installation and "Special Features" guides, and the Compaq color graphics board comes supplied with an installation and operations guide.

The manuals and operations guide are good enough for experienced users, but they lack the completeness that would be required by first-time purchasers.

The *80286-Based Products Technical Reference Guide, Compaq Enhanced Color Graphics Board Technical Reference Guide*, and *Compaq Desktop Maintenance and Service Guide* are available for programmers or technicians. The *MS-DOS Version Reference* and *BASIC Version 3 Reference Guides* are available with their software as an option from Compaq.

The new version of the Deskpro 286 has all the features of its predecessor together with the fast 8/12-MHz clock and CACHE software to boost its performance. As a fringe benefit, it now boasts an enhanced keyboard.

Once Compaq Corporation decides on which audience its Deskpro 286 documentation should address, the company should be more consistent in the amount and level of information to be included. With this improvement (and perhaps blunting the sharp edges of the keyboard), the new Deskpro 286 would be an excellent machine, certainly delivering a better performance than the 8-MHz AT.

—JOHN McCORMICK

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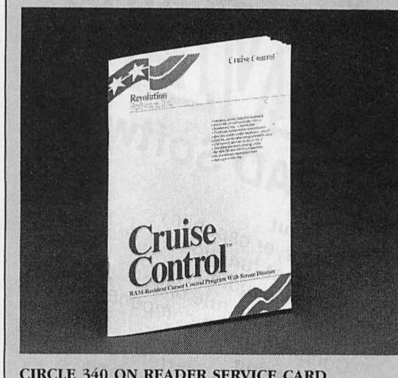

CIRCLE 340 ON READER SERVICE CARD

The proliferation of interesting terminate-and-stay-resident (TSR) utilities and accessories poses a dilemma: which TSRs should be installed and which should be omitted to preserve enough memory for main applications? Cruise Control from Revolution Software, Inc. occupies little memory and greatly improves the user interface of many major applications, making it a top contender for the pole position in any AUTOEXEC.BAT file.

Cruise control permits cursor speed to be controlled from within an application while simultaneously eliminating cursor run-on. All but the most fastidious of those who earn their living with spreadsheets know the frustration of scrolling through a worksheet looking for a desired cell, only to overshoot the target and slam into the worksheet border. As the type-ahead buffer clears itself of accumulated cursor movement commands, the accompanying beeping adds to frustration and sends an audible signal to coworkers that something is amiss.

With Cruise Control installed, the cursor speed may be adjusted to suit the user, permitting increased scrolling speeds for template manipulation. In one test, the time required to scroll down through 8,192 lines of a Lotus 1-2-3 spreadsheet was reduced by more than 75 percent with Cruise Control set at maximum. Scrolling across columns of a maximum-width worksheet was reduced by 12 percent. Another feature, called Anti-Skid Braking, in a continuation of automotive metaphor, stops the cursor when the arrow key is released. The combination of cursor speed control and the elimination of run-on definitely improves the ability to home in on a target cell.

Cruise Control's usefulness is not restricted solely to spreadsheets. Cruise Control's effect on word processing was tested on a 31-page WordPerfect document. With Cruise Control set at maximum, the time that was taken to scroll through the entire document was reduced by more than 50 percent. The time that it took to move the cursor character by character through a page was even more dramatically improved. The cursor speed may be adjusted easily so that it is tailored to fit individual user preference.

Other features included in Cruise Control's repertory include automatic dimming of the CRT after a user-defined time interval, a chronometer that can place the date and/or time (in six different formats) at the cursor position, instant dimming of the screen to protect against prying eyes, and autorepeat of any key without having to hold the key down.

Utilizing Cruise Control from within an application program requires the use of the 5 key on the numeric keypad. With Num Lock off, depressing this key usually has no effect, making it a logical choice for a hot key. Cursor speed may be increased by holding down the 5 key (with Num Lock off) while depressing the + key to the right of the numeric pad. Similarly, the 5 key in conjunction with the − key to the right of the numeric pad reduces cursor speed. Hitting the 5 key and then another key causes the second key to

be repeated, without it having to be held down. The repetition speed is dynamically controlled by touching the + and − keys; it may be varied from one character every 18 seconds to 16 characters per second. Cruise Control permits easy reassignment of the hot key should the default assignment prove inconvenient or should it conflict with another TSR.

Cruise Control may be disabled at any time from within a program by a combination of the hot key and the Ins key. A help feature is available but may be called only from the DOS prompt, not from within an application; however, Cruise Control is so simple to operate that this help provision becomes somewhat superfluous.

Three Control Strategies are provided in version 3.02 that allow Cruise Control to work with different application programs. A list of programs with strategy recommendations is provided with the documentation, and the user has the option of switching between Control Strategies at any time by using the hot key and the Tab key.

In use with other popular TSRs (for example, SideKick, Turbo Lightning, Automenu, and DESQview), no problems were encountered either with Cruise Control or with the operation of the other TSRs. The program ran without any difficulty on several machines, including an IBM PC/XT, a Compaq Portable 286, and an IBM PC/AT with an Enhanced Graphics Adapter. The screen-dimming feature of Cruise Control would not work on a Zenith Z-158 PC clone nor did it work with a new IBM Personal System/2 (PS/2) Model 50, although the other features operated flawlessly. Revolution Software, Inc. says that the current release of the program now supports PS/2 screen blanking and that Cruise Control is currently available on 3.5-inch diskettes. Cruise Control comes with a 60-day money-back guarantee, eliminating the purchaser's risk that it might not work on a specific machine.

Cruise Control is supplied on a single diskette (which is not copy-protected) containing three files totalling 100KB, the bulk of which is for the README and INSTALL files. Installation is the epitome of simplicity; the installation program will copy the Cruise Control software to a hard disk, creating a subdirectory if this is desired, and can be directed to modify the existing AUTOEXEC.BAT file, allowing the user to specify precisely where in the file Cruise Control is to be invoked. The version that was tested required only 4.3KB RAM.

The documentation consists of a 21-page pamphlet that could benefit from a reorganization of its major elements into a more logical sequence. For example, the installation section should precede the section discussing the use of special Cruise Control keys. In spite of this minor organization problem, the documentation is succinct, and the instructions are easy to understand. The README file supplied with the tested version is unique in that, instead of being the usual collection of errata, it is a well-written document complete with a table of contents.

Cruise Control has proven to be an ideal accessory. This package sits unobtrusively in memory until it is needed. Then, it performs its duties well, making minimum demands on the user. The combination of good performance and low price should make Cruise Control popular.

—JUSTIN CROM

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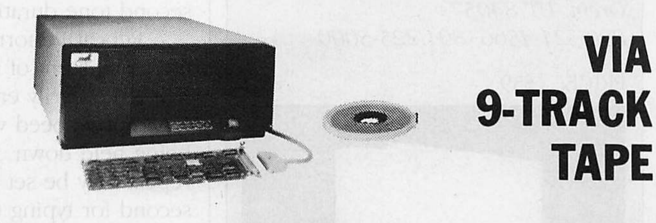

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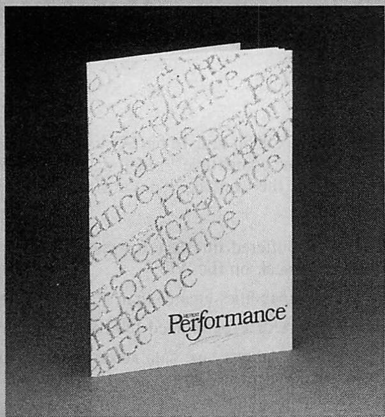

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Repeat Performance is a keyboard enhancement utility program from WordPerfect Corporation that is designed to increase user productivity within application programs such as spreadsheets and word processors. Like Cruise Control, which also is reviewed in this month's Product Watch, Repeat Performance allows the user to control keyboard characteristics such as key repetition rate and type-ahead buffer utilization. Repeat Performance features include adjustment of the delay time between key press and start of autorepeat, modification of the type-ahead buffer size, setting of a temporary high-speed repeat overdrive, calibration of the frequency and duration of the computer's beep tone, and override of the "Reverse Caps Lock" keyboard characteristic. The Repeat performance program is completely flexible and easy to tailor on an ad hoc basis for temporary special requirements. Repeat Performance version 2.0 was used for this review.

Repeat Performance permits greater control over several keyboard parameters. With this program, the key repeat speed (rate at which keys repeat when held down) is adjustable between 1 and 1,000 characters per second, the repeat delay (the pause time before the key begins repeating) from 0.10 to 100 seconds, the type-ahead buffer size from 15 to 1,000 characters, the beep-tone frequency from 50 to 5,576 Hz, and the tone duration from 0.01 to 2.5 seconds. For comparison, the IBM PC keyboard standard values are 11 characters per second repeat speed, a 0.50-second repeat delay, a 15-character type-ahead buffer, an 896-Hz beep-tone frequency, and a 0.5-second tone duration.

Repeat Performance also allows the assignment of a Turbo Button that will temporarily enhance a key's autorepeat speed while the key is being held down. For example, key repeat may be set at 40 characters per second for typing (a relatively fast setting), with a turbo setting of 100 characters per second; pressing the turbo key (default to Ctrl, but can be set) while a cursor arrow key is held down will temporarily increase the repeat rate to 100 repeats per second, as long as the turbo key is depressed. This allows rapid cursor movement as required (or the repeat of other characters such as graphics symbols during line-drawing operations) without forcing a compromise between repeat speed for typing and cursor movement. This feature operates in a natural, intuitive manner and can significantly improve productivity for tasks such as text or spreadsheet editing.

Skid Squelch is the term used to describe the program characteristic that prevents "cursor skid" when an application program cannot keep up with a key repeat rate; Repeat Performance automatically adjusts the key repeat speed on the fly to match the processing speed of the program, so no characters remain in the type-ahead buffer when the key is released. Skid Squelch worked well with the wide variety of applications used for testing purposes over a three-month period; this feature is a must when high repeat rates are required.

For typists who must switch between typewriters and word processors, or for other users who frequently work with the CapsLock key on, the IBM PC's reverse CapsLock feature can be irritating in some situations; with CapsLock on, the computer's shift keys shift the character keys to lowercase. With the reverse CapsLock characteristic disabled by Repeat Performance, the shift keys can be used to access the characters that are not shift-locked (such as the special symbols above the number keys), without shifting alphabetic characters to lower case.

Repeat Performance also permits special nonkeyboard characters (ASCII value entered on the numeric keypad with the Alt key depressed) to be repeated. The Alt and Shift keys are held down while entering the ASCII value, then the Alt key is released; the character will repeat until the Shift key is also released. This feature is very useful in line drawing and other special character editing operations.

Repeat Performance is installed as a device driver rather than as a terminate-and-stay-resident (TSR) program, and default settings are specified as parameters on the device= line in the CONFIG.SYS file. An interface program, RP.EXE, communicates with the installed device driver to make temporary adjustments to the default settings. RP.EXE also can be used to control the load position of TSRs relative to the Repeat Performance device driver to ease difficulties that may occur with some TSR programs; specific instructions are included in the documentation for use with several programs such as Quarterdeck's DESQview and Borland's SideKick and SuperKey.

Option parameters included on the device-driver line set default values. RP.EXE can be used interactively to adjust the default values, or new values may be passed as parameters on the RP.EXE command line. All of the Repeat Performance parameters may be adjusted by RP.EXE without requiring the system to be rebooted.

RP.EXE provides an easy interface for adjusting the repeat speed and delay settings; the cursor left and right arrows move pointers along scales for speed (1 to 1,000 characters per second) and delay (100 to 0.10 seconds), and a typing area is used to test the settings before saving them. Similar screens are used to set and test the turbo speed and key assignment parameters as well as the beep-tone frequency and duration.

An installation program named RPINSTAL.EXE may be used to copy the Repeat Performance programs to a hard disk, set the default parameters, and generate a device= entry into the CONFIG.SYS file (placed on the first line, but may be moved with a text editor). The installation program is not required because the CONFIG.SYS entry may be made with any editor.

Repeat Performance is an impressive program. It provides complete control over a wide variety of keyboard parameters with a powerful, flexible, and intuitive user interface. Users who spend significant time with word processing, spreadsheet, text editor, or other cursor-intensive programs can realize substantial improvements in productivity with little effort.

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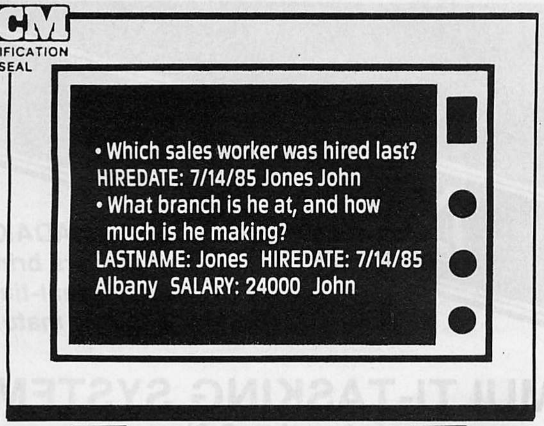

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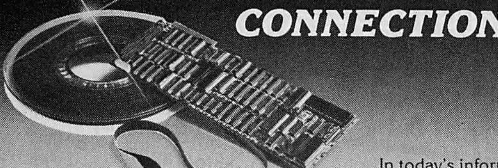

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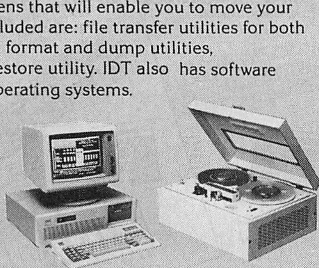

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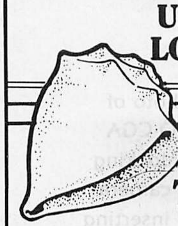

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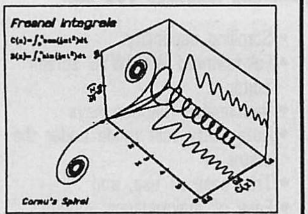

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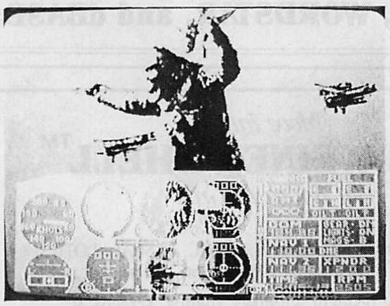

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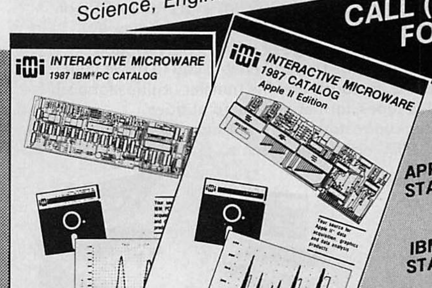

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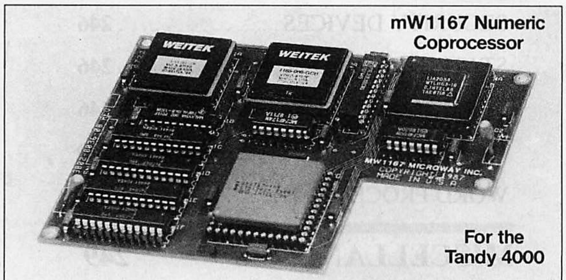

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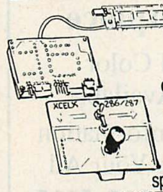

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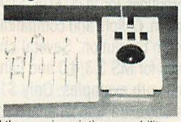

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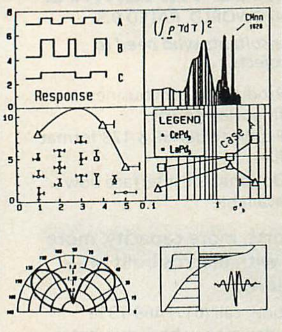

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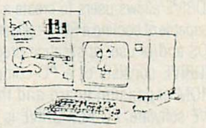

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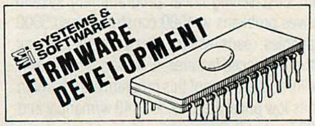

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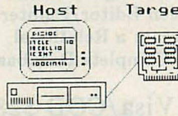

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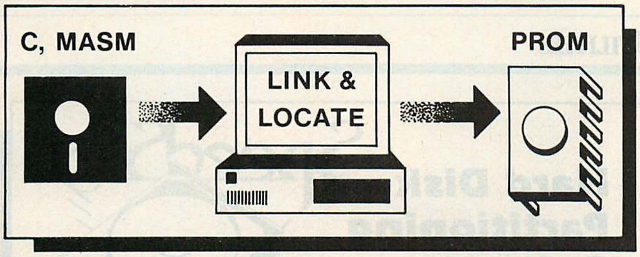

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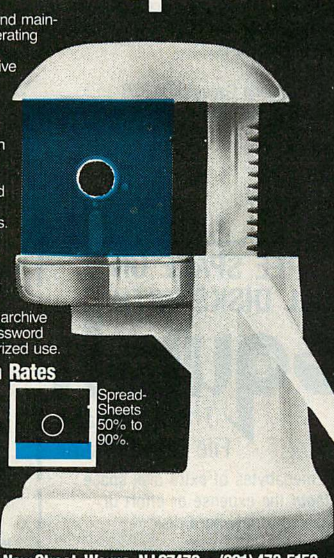

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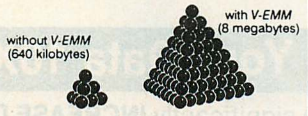

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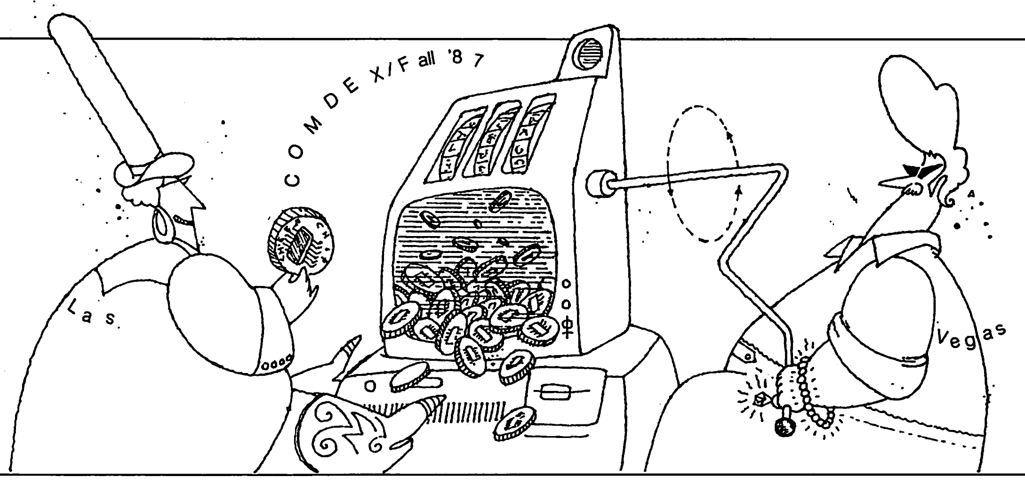

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November 11–13
Optical Publishing and Storage
New York, NY (Learned Information) *Contact:* Learned Information, Inc., 143 Old Marlton Pike, Medford, NJ 08055; 609/654-6266

November 17–19
Wescon '87 Electronics Show
San Francisco, CA (IEEE and ERA) *Contact:* Alexes Razevich, Wescon '87, P.O. Box 92275, Los Angeles, CA 90009-2275; 213/772-2965

DECEMBER

December 1–3
Realtime Systems Symposium
San Jose, CA (IEEE-CS) *Contact:* Prof. Kang G. Shin, Dept. of EE and CS, University of Michigan, Ann Arbor, MI 48109-1109; 313/763-0391

December 1–3
Optical Information Systems '87
New York, NY (Conference Management Corporation) *Contact:* Meckler Publishing, 11 Ferry Lane W, Westport, CT 06880; 203/226-6967

December 6–9
International Conference on Information Systems
Pittsburgh, PA (Society for Information Management) *Contact:* William D. King, Graduate School of Business, University of Pittsburgh, Pittsburgh, PA 15260; 412/648-1587

December 7–8
Fault Tolerance in Parallel and Distributed Computing
San Diego, CA (IEEE-CS) *Contact:* Prof. Miroslan Malek, Dept. of EE and CE, University of Texas, Austin, TX 78712; 512/471-5704

December 7–9
National Connectivity Symposium on LAN and Links
Washington, DC (Digital Consulting, Inc.) *Contact:* Seminar Services, 6 Windsor Street, Andover, MA 01810; 617/470-3880

December 14–16
Winter Simulation Conference
Atlanta, GA (IEEE-CS) *Contact:* Hank Grant, Factrol, Inc., 1305 Cumberland Avenue, P.O. Box 2569, West Lafayette, IN 47906; 317/463-5559

December 16–18
Microcomputer Graphics '87
New York, NY (Expoconsul International) *Contact:* Expoconsul International, Inc., 3 Independence Way, Princeton, NJ 08540; 609/987-9400

JANUARY

January 5–8
Hawaii International Conference on System Sciences
Kailu-Kona, HI (IEEE-CS) *Contact:* Ralph H. Sprague, Jr., Decision Sciences Dept., University of Hawaii, 2404 Maile Way, E-303, Honolulu, HI; 808/948-7430

January 13–15
Design Automation Workshop
Appache Junction, AZ (IEEE-CS) *Contact:* Walling Cyre, Control Data, HQM 173, P.O. Box 1249, Minneapolis, MN 55440; 612/853-2692

FEBRUARY

February 8–11
UniForum '88
Dallas, TX (The International Network of UNIX Users) *Contact:* UniForum '88, 2400 E. Devon Avenue, Suite 205, Des Plaines, IL 60018; 800/323-5155; 312/299-3131

February 16–18
DEXPO East '88 Conference
New York, NY (Expoconsul International) *Contact:* Expoconsul International, Inc., 3 Independence Way, Princeton, NJ 08540; 609/987-9400

February 22–24
Computer Graphics New York
New York, NY (Exhibition Marketing and Management, Inc.) *Contact:* EMM, Inc., 8300 Greensboro Drive, Suite 1110, McLean, VA 22102; 703/893-4545

February 23–25
Computer Science Conference
Atlanta, GA (ACM) *Contact:* Dr. Richard A. DeMillo, Program Chairman, Software Engineering Research Center, Georgia Institute of Technology, Atlanta, GA 30332; 404/894-3180

MARCH

March 7–10
Computer Workstations
Santa Clara, CA (IEEE-CS) *Contact:* Patrick Mantey, 335A Applied Science Bldg., Dept. of Computer Engineering, University of California at Santa Cruz, Santa Cruz, CA; 408/429-2158

March 8–11
International Seminar on Digital Communications
Zurich, Switzerland (IEEE-CS) *Contact:* Secretariat 1ZS 88, c/o P. Gunzburger, Hasler AG, TDS, Belpstrasse 23, CH-3000, Bern 14, Switzerland; 41-31-632808

March 20–24
NCGA Annual Conference and Exhibition
Anaheim, CA (National Computer Graphics Association) *Contact:* NCGA, 2722 Merrilee Drive, Suite 200, Fairfax, VA; 703/698-9600

March 21–23
Computer Standards Evolution: Impact and Imperatives
Arlington, VA (IEEE-CS) *Contact:* Computer Standards Conference, IEEE, 1730 Massachusetts Avenue, NW, Washington, DC 20036-1903; 202/371-0101

March 21–25
World Users Conference
Los Angeles, CA (MacNeal-Schwendler Corporation) *Contact:* The MacNeal-Schwendler Corporation, 815 Colorado Blvd., Los Angeles, CA 90041; 213/258-9111

March 28–31
World Congress on Computing
Chicago, IL (The Interface Group, Inc.) *Contact:* The Interface Group, Inc., 300 First Avenue, Needham, MA 02194; 617/449-6600

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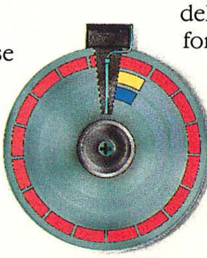

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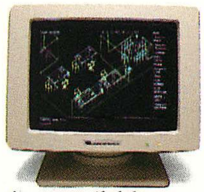

You can even run up to nine applications at once. Without memory limitations. Because all enhanced ALR systems include the bestselling multitasking software Desqview,™ as well as QEMM,™ an EMS management utility.

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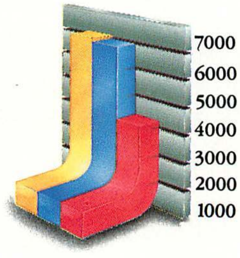

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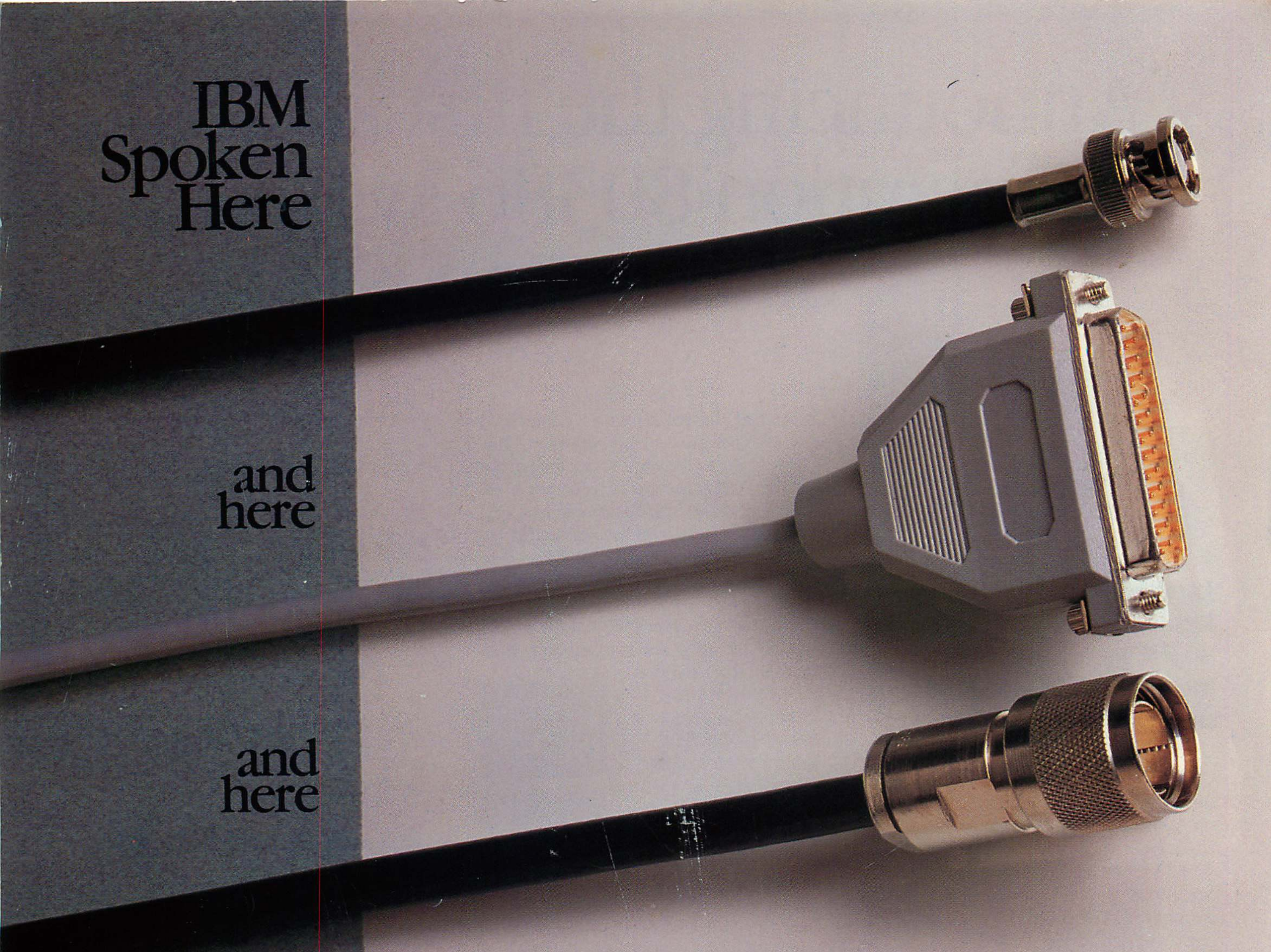

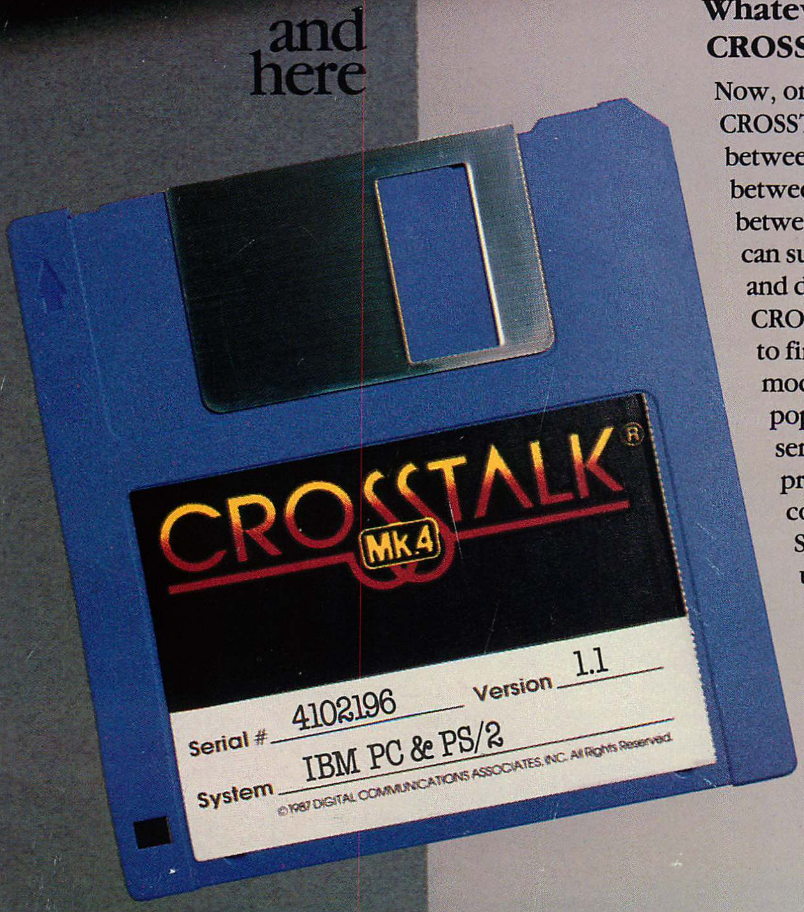

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